DRIVER'S COMFORT LEVEL IN CONSTRUCTION ZONES WITH REDUCED TRANSITION TAPER LENGTH: CASE STUDY FOR PAKISTANI CONDITIONS

BY

RIAZ AHMED KHAN

THESIS

Submitted in partial fulfillment of the requirements
for the degree of Master of Science in Civil Engineering
in the Graduate College of the
University of Illinois at Urbana-Champaign, 2011

Urbana, Illinois

Advisor:

Professor Rahim F. Benekohal

ABSTRACT

There are no detailed specifications for work zone (WZ) traffic control plan in Pakistan whereas MUTCD in the US provides for very detailed traffic control plans for WZs. Pakistan needs to develop its specifications by adopting in-practice standards to its conditions. This study aims at analysis of comfort level with reduction in taper length in Pakistani WZ conditions. A web based survey was conducted with 108 participants to assess drivers' comfort level if taper length is reduced on motorways and highways by 0%, 10%, 29%, 30% and 40%. It focused on people having driving experience in Pakistan and US. It was concluded that age was a significant factor for 20% and 30% reduction in the taper length for motorways and for 10% reduction for highways. Driving experience in Pakistan was a significant factor for 30% and 40% reduction for motorways but not for highways. People from higher age groups and people having Pakistani driving experience of more than 10 years were over represented in uncomfortable category. Province of residence in Pakistan was a significant factor for 10% and 20% reduction on taper length on motorways and for 20% and 40% reductions on the highways. State of residence and driving experience in the US were not significant factors. For reductions up to 20%, majority of drivers was either in "comfortable category" or in "neither comfortable nor uncomfortable category". However, for 30% reduction majority was in "uncomfortable category". Average comfort level for respondents on motorways is greater than that on highways for reduction up to 30%. A 20% reduction in taper length brings the average comfort level to 3.108 for motorways and 2.891 for highways, whereas a value of 3 indicates "neither comfortable nor uncomfortable". A 30% reduction in taper length brings the average comfort level to 2.439 for motorways and 2.241 for highways.

Finally, a reduction of 25% in taper length is recommended for motorways and highways and it is suggested to study this recommendation in Pakistani work zones at those sites where the safety of motorist is not compromised.

ACKNOWLEDGEMENTS

I would like to thank my advisor Dr. R.F Benekohal whose guidance made it possible for me to complete this research. He made himself available whenever I asked for. His ability to make things look easy in moments of despair is admirable. Lenient in behavior but strict in maintaining high standards, I enjoyed working with him.

I would also like to thank all those people who took out time to participate in the survey, all my friends especially Mr Rajesh (Ex-President Pakistani Graduate Students Association) who used his personal contacts to distribute the survey in other states and Consulate General of Pakistan in Houston who also helped in circulating the survey in Pakistani community.

I would also like to appreciate my friend Syed Tahir Abbas Shah (PhD student at UIUC) who guided me through designing of the web based survey.

TABLE OF CONTENTS

CHAPTER 1

INTRODUCTION

Pakistan is a developing country with 6^{th} highest population in the world with a total estimated population of 178.9 Million. The country's per capita GDP (Gross Domestic Product) is $ 955 as compared to India's $1192 and US' $ 45,989 (World Bank, 2009). Developing countries like Pakistan are struggling to put an adequate infrastructure in place to support an expanding economy.

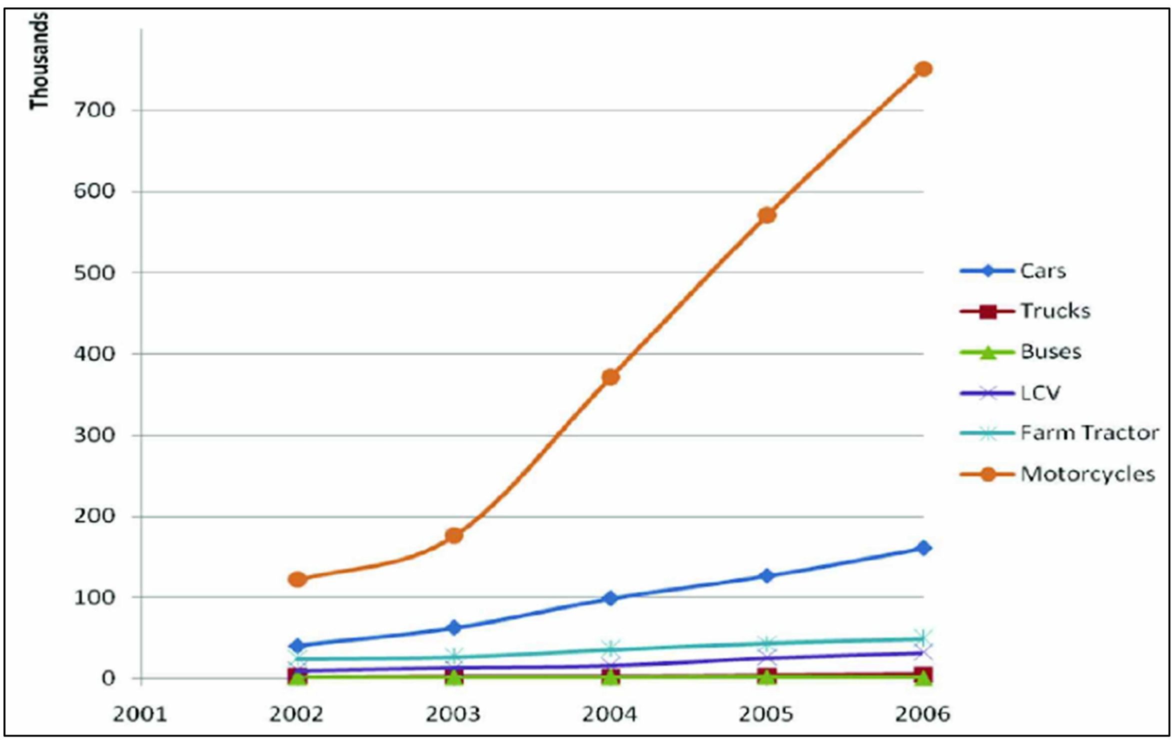
Pakistan has 8318 Km of national highways and 576 Km of motorways in operation. A total of about 2000 Km of motorways is planned (PTPS, JICA 2006). Motorways are restricted entry, multilane roads with speed limit of 120 kph and highways are open entry roads with speed limit of 90 kph. Motorways are equivalent to interstate highways in the US. According to a Road Safety Report issued by Ministry of Communication, Pakistan (2007), "there has been tremendous growth in the automobile sector in the recent past five years. Vehicle production, including cars, trucks, motorcycles, tractors, buses and other commercial vehicles, has sky rocketed from 195,791 units in 2001-02 to 998,592 units in 2005-06 (Increase by 410%). Passenger cars and light commercial vehicles have seen substantial growth; from 50,000 units per/year have grown to about 200,000 units/year (Increase by300%). Motorcycles have had the highest growth, increasing from 120,000 to 50,000 units/year (Increase by 525%)." Fig 1.1 shows the rate of yearly increase of motorization in Pakistan.

1.1 Facts About Pakistan

Following is a summary about the country for readers who are not familiar with Pakistan.

• Location	South Asia
• Population	178.9 Million
• Area	796,096 Sq. Km
• Length of Motorways/Highways	8,894 Km
• Provinces	4 (Punjab, Sindh, Khyber Pukhtunkhwa, Balochistan)
• Territories	Capital Territory (Islamabad) Gilgit Baltistan FATA (Federally Administered Tribal Areas) Azad Kashmir

Fig 1.1 Motorization in Pakistan



Source: Road Safety Report (M.O.C)

1.2 Road Accidents Data for Pakistan

In a study Razzaq, J.A et al (1998) showed that official sources counted only 56% of deaths and 4% of serious injuries. This is a serious under reporting and this must be kept in mind while talking about road accidents in Pakistan.

According to National Transport Research Center's statistics there were 4,527 fatal accidents and 6,060 non-fatal accidents resulting in 5,421 fatalities and 12,942 injuries in 2001. Table 1.1 provides accident data from 1996 to 2001.

Pakistan Transport Plan Study (2006) by JICA (Japan International Cooperation Agency) observed that "While the road safety study conducted by the NHA in 1998-99 estimated 7,000 fatalities, 140,000 injuries and 1,400,000 property damages based on sample surveys carried out in four provinces, a recent study by the ADB indicated that the road traffic accidents involve over 10,000 fatalities per year (over 30 per 10,000 vehicles) and 150,000 injuries. These are high levels compared with Southeast Asia, although better than those in India and Bangladesh".

Table 1.1 Accident Data for Pakistan

Year	Fatal	Non-Fatal	Others	Total	Killed	Injured	Total
1996	4,383	5,369	2,938	12,690	5,301	11,697	16,998
1997	4,407	5,249	2,737	12,393	5,141	11,229	16,370
1998	3,620	4,317	418	8,355	4,196	9,817	14,013
1999	4,637	5,635	449	10,721	5,371	11,797	17,168
2000	4,629	6,114	409	11,152	5,627	13,479	19,106
2001	4,527	6,060	338	10,925	5,421	12,942	18,363

Source: Accident Statistics (1991-2001), NTRC

However, World Health Organization (WHO) has provided data for road accident deaths in different countries. Table 1.2 provides a comparison of WHO accident data for Pakistan and its neighboring countries along with data for the United States. It can be seen that death rate in Pakistan is not better than India and Bangladesh.

The JICA report has estimated number of accidents from newspapers. The estimate is given in Figure 1.2.

In a study, Bhatti et al (2010) compared traffic data for normal traffic flow and traffic flow through a work zone on a Pakistani highway and showed that a total of 180 crashes were identified from the police registers on an under construction stretch of 196 Km of highway.

Table 1.2 Comparison of Road Accident Data

Country	Year	Number of registered vehicles	Death rate (per 10,000 Population)
Afghanistan	2007	731,607	39
Pakistan	2006	5,287,152	25.3
India	2004	72,718,000	16.8
Bangladesh	2007	1,054,057	12.6
Iran	2007	17,000,000	35.8
United States	2006	251,422,509	13.9

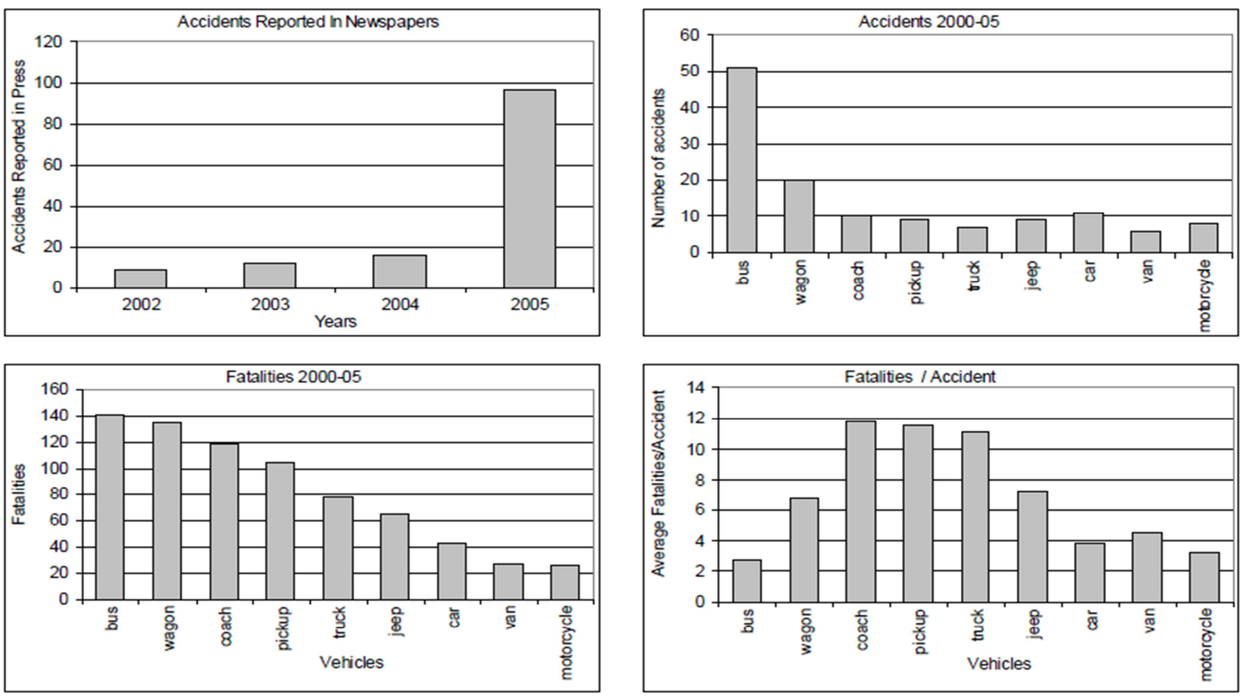
Source: World health organization

Overall, 612 road users were injured in these crashes; 14.8% died, and 55.3% were severely injured. The road death rate on this highway, excluding highway work zone (HWZ) crashes, was 13.0 per 109 vehicle-km. Compared with trucks, the crash rate was lower for passenger cars but the death rate was twice as high for passenger cars as for trucks. Similarly, death rate was significantly higher for occupants of buses and minivans than for truck occupants. Fifteen percent of the traffic crashes occurred in the HWZ, accounting for 0.8% of all fatalities and 15.3% of those severely injured on the 196 km road section. The HWZ accounted for 17.6% of the vehicle- km travelled on this subsection. Two HWZs were 10 and 14 km long and lasted more than 300 days. The crash and death rates observed in normal traffic zones of this subsection were similar to those for the whole road section, whereas the rate of severe injury was higher than for the whole road section. Significantly higher risks of crash, death and severe injury were observed in the HWZ than in other zones in this subsection.

1.3 Current State of Road Safety in Pakistan

Pakistan spends a meager amount on road safety especially on highway work zone traffic management. According to Road Safety Report issued by Ministry of Communication, Pakistan (2007), Pakistan has spent $0.07 per capita (0.015% of GDP/capita) on road safety in 1998 whereas, Road safety spending comprises a greater share of public spending in countries such as the United Kingdom (population 56 million) where the government spends roughly £1 billion per year (1980 prices) on road safety.

Fig 1.2 Accident Data for Pakistan from News Papers



Source: Pakistan Transport Study Plan

The report further states that work zones are poorly designed and the devices used for this purpose do not meet international standards and there is no pay item for this purpose in the contracts. The report has recommended that courses should be taught about road safety and traffic engineering at both under graduate and graduate levels and to establish road safety directorates in public highway departments.

1.4 Need for Research

Pakistan is lacking in basic work zone traffic management due to various reasons such as limited funding, lack of interest at policy making level and little regard for minimal safety standards etc. As a consequence very limited research has been done in the field of work zone traffic management. Currently there are no specifications for work zone traffic management in Pakistan. WHO includes Pakistan in the list of countries for "no specification of targets for national road safety strategy."

As already discussed, number of personal vehicles in Pakistan is rapidly increasing. This increased motorization is putting heavy burden on existing road network which requires expansion, widening and maintenance. According to Pakistan Transport Plan Study by Japan International Cooperation Agency (JICA 2006), "The highway network configuration in Pakistan has almost been completed. However, most sections except N-5 are single lane roads (one lane per direction), which has a limited capacity as well as problems to secure safe traffic. Therefore, the main focus of road investment will be "widening" rather than "new construction. By 2025, many highways will need widening into dual-2 carriageway due to heavy demand exceeding present capacity, especially in Punjab province".

Keeping in view the condition of roads, there is a dire need for maintenance and widening of existing roads in near future. However, if specification for highway works zone traffic management are not prepared timely, more safety risks would result from a large number of un-managed work zones.

1.5 Objective of the Research

Taking into account a broader view of the scenario in the field of traffic management in Pakistan, it is high time that traffic management is considered as a priority at policy making level. In the absence of an internationally comparable and locally calibrated traffic management plan economic losses in terms of human life, fuel consumption, time and environment would incur. This research is undertaken with a view that Pakistan needs a thorough traffic management plan. Preparation of such a plan would need a deliberate and concerted effort.

Work zone traffic plan is a more critical area of traffic management in terms of safety and capacity since each work zone presents the drivers with a unique and unexpected situation to cope with. Plenty of research has been done in developed countries on work zone traffic management to increase safety and capacity and to decrease delay while travelling through work zones. Work zone traffic management consists of a series of steps such as warning signs, channelization etc, taken to avoid accidents and to allow a smooth, unhindered flow. All aspects of work zone traffic plan need to be studied and adopted according to Pakistani conditions.

A more logical approach is to proceed in steps, i.e as a first step, look at specifications and research from developed countries and adopt a reduced but equally safe version of these specifications. The adopted version should be based on research done on that particular aspect. This would allow to start good traffic management in Pakistan at a lower cost and to develop traffic safety culture. Once initial plans are in place, more elaborate specifications can be prepared later on based on the data from in place plans.

This thesis looks into only one aspect of work zone traffic management i.e “Taper Length”. 1971 version of MUTCD contained only one equation for taper length. However, another equation was included in the later versions to reduce the taper length for lower speeds. Since 1978, there has been no change in these equations despite a significant change in vehicle characteristics and traffic flow patterns. In this thesis, effort is to see if a reduced taper length than current MUTCD equations is feasible in Pakistani conditions.

1.6 Scope of the Research

This thesis is about a particular aspect of work zones on highway. It deals with transition area in a work zone. If one of the two or more lanes (in each direction) of a highway is closed due to work activity, the traffic would need to be re-directed to the open lane. This is not done abruptly instead a transition is provided on closed lane for traffic to merge into open lane. Length of this transition is given in MUTCD (to be described in detail later). The thesis deals with road user's response to decreased transition area in Pakistani conditions. A survey is used to measure response of people. The survey focuses on people who have driven both in the US and Pakistan. Further to this, the research is limited only to straight sections of highways where one of the two lanes is closed due to work.

CHAPTER 2

LITERATURE REVIEW

This chapter provides an insight to the research and specifications related to the highway work zones.

2.1 Specifications

2.1.1 Manual on Uniform Traffic Control Devices (MUTCD)

It is very often required to carry out work on highways which causes hindrance in normal flow of traffic. Temporary traffic control (TTC) plans are enforced for continuity of the movement of traffic, pedestrians and all related operations. Drivers face constantly changing scenarios while passing through a TTC zone. This increases vulnerability to accidents. Primary objective of a TTC plan is to manage traffic smoothly and increase safety of people passing through a work zone and those who are working in.

MUTCD 2009 provides following basic principles for setting up a work zone plan.

a. Safety:

Safety measures for normal highway operations should also govern traffic operation through a TTC zone as nearly as possible. All TTC plans should be prepared in advance of start of work in view of all factors.

b. Minimum possible hindrance:

Frequent and abrupt changes in the roadway should be avoided and all changes should be kept to minimum and such changes, if necessary should be gradual. Work should be carried on at a time of minimum traffic (e.g off peak or night time), if possible. Since the capacity of a work zone is less than normally operating highway, methods should be adopted to reduce traffic volume passing through a work zone.

c. Clear guidance:

Clear marking and signage should be used to guide all users through a work zone.

d. Inspection:

Once the TTC is in place, it should be continually monitored under all possible traffic changes and for crashes and changes should be made accordingly.

f. General:

TTC should be maintained properly, user needs should be kept in mind and good public relations should be maintained.

Construction zone is divided into four parts. Fig 2.1 shows a typical layout of a construction zone.

a- Advance warning area: AWA is provided to inform the drivers to expect construction ahead on the highway. AWA is usually about 1000 ft to 2640 ft on a highway/freeway depending upon speed limit and number of lanes.

b- Transition area: The transition area is the section of highway where road users are redirected out of their normal path.

c- Activity area: This is the area where actual construction is carried out. All the machinery and workers are present here. It is further divided into work space, traffic space and buffer space.

d- Termination area: This is the downstream end of the work area. It is provided to return traffic to its normal path.

2.1.1.1 Transition Area

Transition area may consist of shoulder, merging or shifting taper. Merging taper is required when one of the lanes is closed due to construction. It is provided to facilitate driver to reduce speed and merge into operating lane. MUTCD (2009) provides the following formula for calculation of merging taper length.

For speed 40 mph or less: $L = \frac{ws^2}{60}$ (1

For speed 45mph or more: L= ws (2

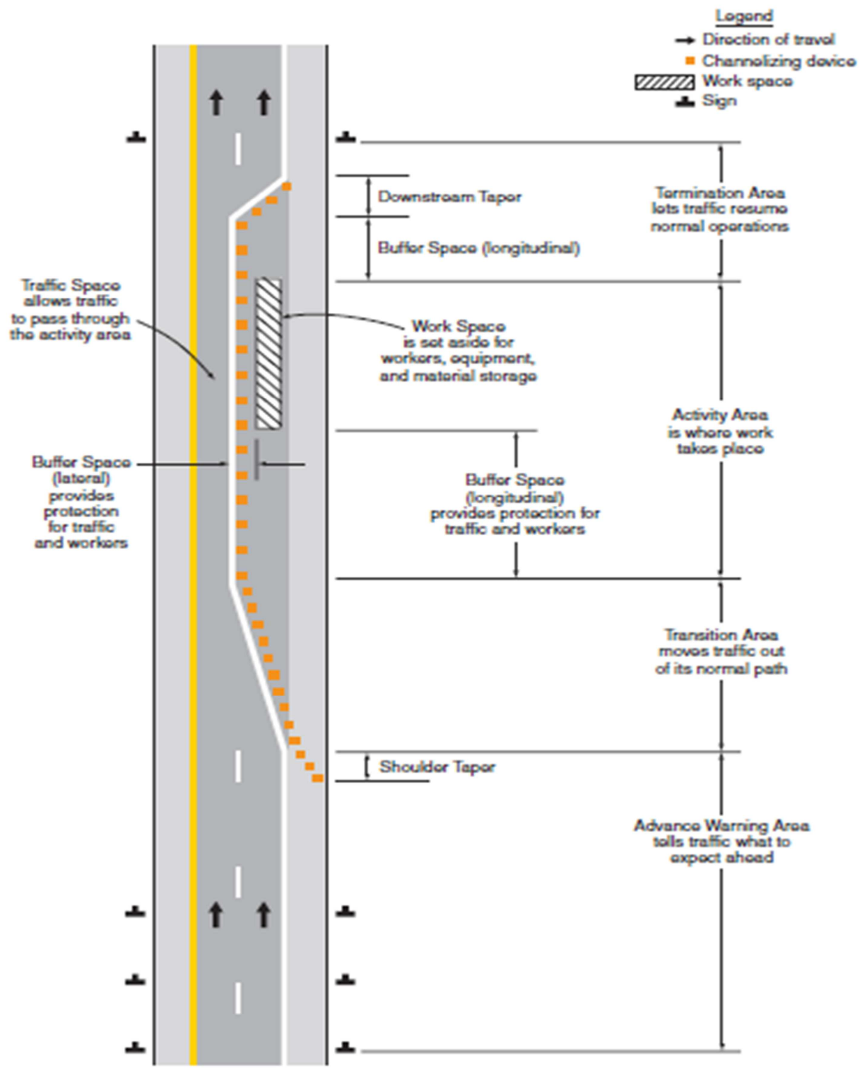
Where L = Taper length (ft).

W = width of offset (ft)

(Offset is lateral shift that a vehicle has to go through while merging into open lane. Usually it is equal to lane width).

S = Posted speed limit (mph)

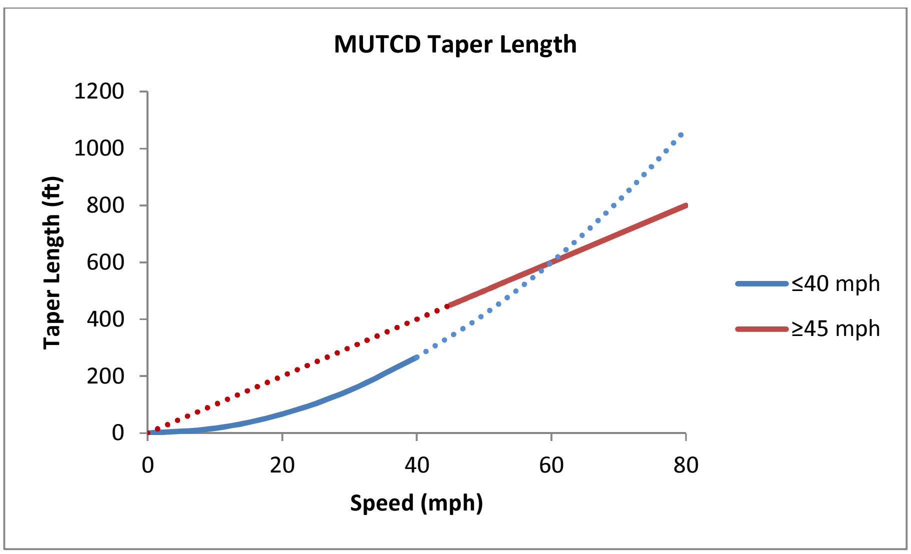
Fig 2.1 Schematics of Work Zone



Source: MUTCD 2009

Taper length form Equation 1 should be used for approach speed of up-to 40 mph. Only Equation 2 was given for calculating the taper length in 1971 version of MUTCD, (MUTCD 1971) which gave higher taper lengths at speeds lower than 60 mph as shown in Fig 2.2. However, in 1979 Douglas W. Harwood (W. Harwood, 1979) proposed Equation 1 which is applicable to urban streets with posted speed limit of 40 mph or less. This was later on incorporated in MUTCD. Equation 2 is simply a product of speed and offset which means that for every 1 mph increase in speed, an increase equal to offset is required in the taper length.

Fig 2.2 Comparison of Equations 1 and 2

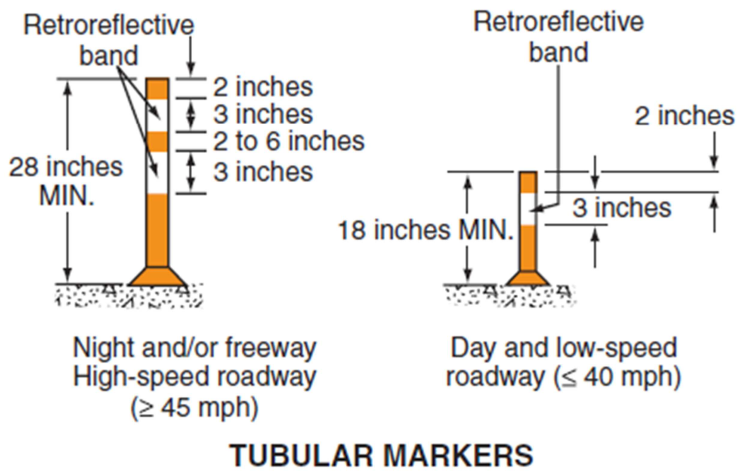


Taper length has not been investigated since 1979 despite immense changes in vehicle characteristics and traffic flow patterns. This study looks into possibility of having decreased taper length on highway work zones. Since this thesis deals only with straight portions of Pakistani highways and motorways where the posted speed limit is 120 Km/h (75 mph) and 90 Km/h (56 mph) respectively, only Equation 2 is used to calculate taper lengths. Transition from two lanes to one lane is achieved over the taper length using different channelizing devices. These devices delineate vehicle path for merging the closed lane traffic to open lane.

2.1.1.2 Channelizing Devices

Section 6F.63 of the MUTCD provides detailed specification of channelizing devices such as cones, drums, tubular markers and barricades. Fig 3 provides a summary of these devices.

Fig 2.3 Channelizing Devices



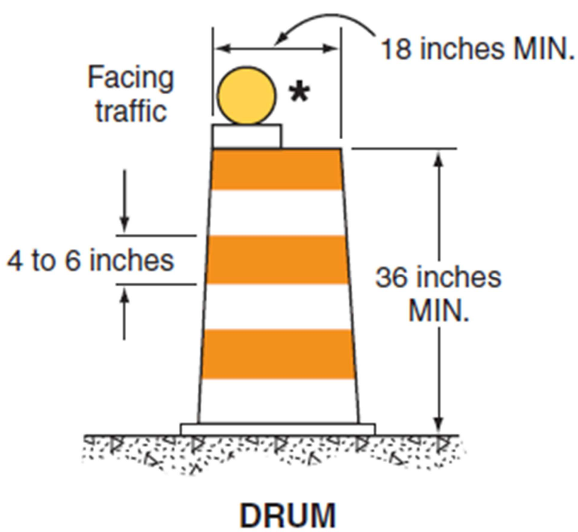
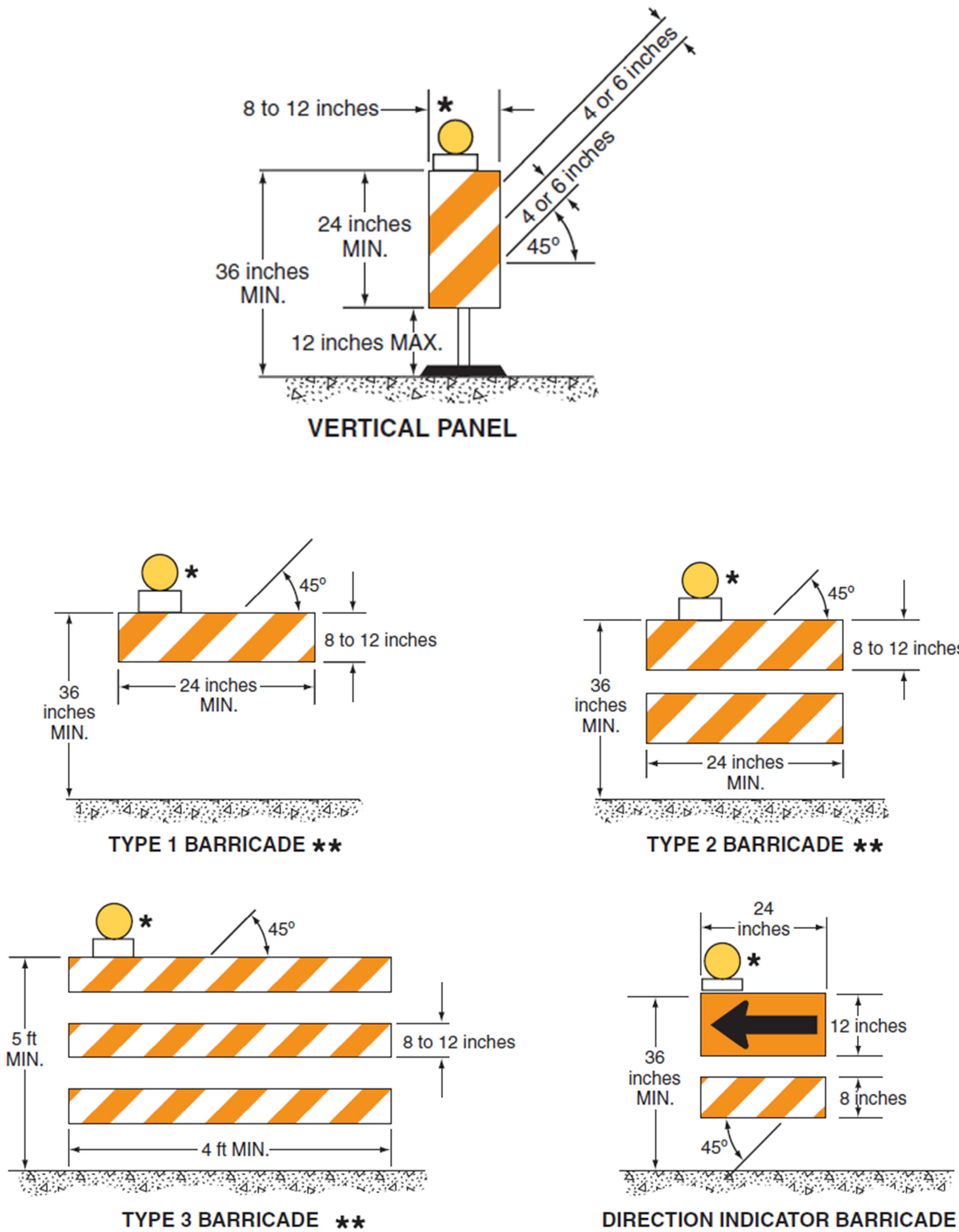


Fig 2.3 (Cont.)



Source: MUTCD (2009)

2.1.2 General Specifications of National Highway Authority Pakistan

The specifications provide a very general view. Following is excerpt that deals with construction zone traffic management.

"The Contractor is allowed to carry out rehabilitation work on half carriage way and direct the traffic on the other half. However if he opts to divert the traffic on temporary road for ease in construction he shall provide, maintain and remove on completion of the works forwhich they are required, all Temporary Road Works such as, detours, tracks over unstable ground and bridges over streams and shall make them safe and suitable in every respect for maintaining two way diverted traffic. Such temporary diversion structures shall be constructed to the satisfaction of the Engineer.

In order to facilitate traffic movement through or around the works, or wherever ordered by the Engineer, the Contractor shall erect and maintain at prescribed points on the works and at the approaches to the work, traffic signs, signals illumination, flares, barricades and other facilities required by the Engineer for the direction and control of traffic. Where required, or where directed by the Engineer, the Contractor shall furnish and station competent flagmen, whose sole duty shall consist of directing the movement of traffic through or around the work."

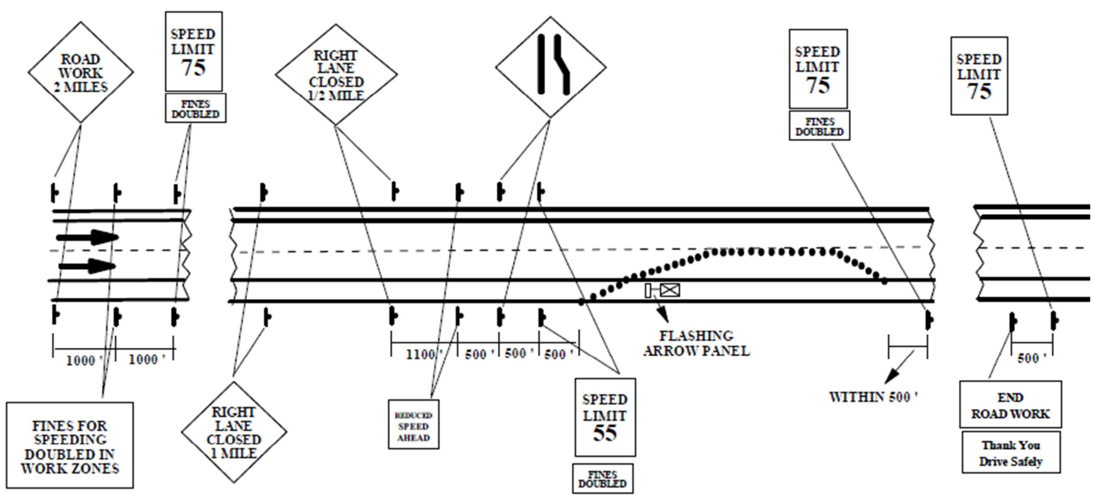
It is quite clear that the specifications are incomprehensive and provide arbitrary powers to the "Engineer". In fact, there is no detail of equipment and lengths given in these specifications for traffic control in construction zone. These specifications need to be elaborated for safe traffic control in work zones.

2.2 Merge Maneuver

MUTCD provides for three types of tapers, namely merge, shoulder and shift tapers. Length of merge taper is given by Equations 1 or 2. Shift taper is half and shoulder taper is 1/3rd of merge taper where ever required. This thesis deals only with merge taper.

In a work zone, closed lane traffic has to perform merge maneuver which is facilitated by taper length. It therefore requires sufficient length to accommodate the maneuver. There are two major arrangements for merging traffic to open lane namely early and late merge. In early merge system, signs are placed at a distance of two, one and half mile upstream of start of transition area so as to make the drivers aware of unusual road conditions ahead. This way vehicles are not squeezed waiting to merge at the beginning of the taper. This also reduces chances of rear end collision by informing the drivers about the bottle neck ahead. According to a study, average number of stops, average duration of the stopped time delay per run and number of aggressive driver maneuvers during the peak hours are reduced by early merge. (Tapan Datta et al. 2001).

Fig 2.4 Early Merge Arrangement

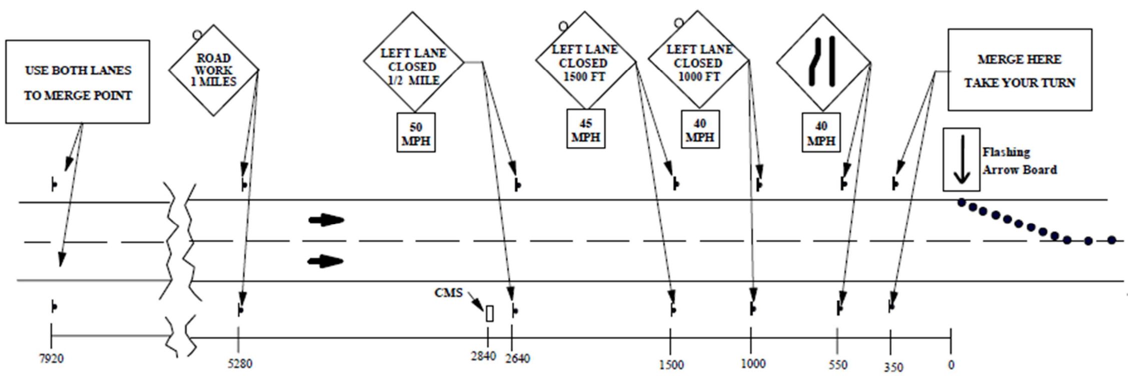


(Source: Patrick T. McCoy et al, 2001)

On the other hand, late merge arrangement allows vehicles to travel in both lanes until they are very close to the taper. This gives more capacity since two lanes are used for a longer distance. This causes lesser competition between drivers in the open and closed lanes. Studies by Christine et al (2001) and Andrew G. Beacher et al (2005) have shown that late merge reduces driver rage, increases density and capacity. Late merges also decrease accident potential by reducing the queue length. However, late merge system increases stop and go maneuver and drivers may start merge at different points resulting in multiple merging points.

According to study by McCoy and Pesti (1999), late merge resulted in 75% fewer forced merges and increase in capacity from 1340 to 1470 passenger cars per hour than early merge and according to Walter et al (2001), late merge delayed the onset of congestion by 14 min than early merge.

Fig 2.5 Late Merge Arrangement



(Source: Patrick T. McCoy et al 2001)

Both early and late merge arrangements have pros and cons but in current practice the taper length used in work zones is not dependent on adoption of any of these arrangements. The relationship between merge type and taper length should be studied and possibility of altering taper length based on adoption of merge arrangement should be looked at.

Driver's characteristics are the most important factor affecting number of road accidents and aggressive merge patterns and age is the among the most influential driver's characteristics.

2.3 Age Factor in Road Accidents

Driving is a complex decision making process which requires agility and quick response to a given roadway condition. The roadway condition gets even more complex while passing through a work zone. Age decreases perception and slows down reaction resulting in increased reaction time. Kevin (2009) showed in his study that older driver's speeds approaching the work zone tend to be slower and have more variance than other drivers and that older driver make less uniform merge patterns. Hoyer et al (1987) showed that older drivers react slower to an unexpected situation. This puts older drivers in a disadvantageous position in circumstances like driving through a work zone. Study by Mihal and Barret (1976) showed that relationship is stronger between reaction time and crash involvement for "older drivers only" than for "total sample size". In response to a question "How do arrow boards, taper drums, and barriers influence driver behavior in terms of speed selection and lane changing maneuvers from the merge point through the workzone and does this driver behavior differ by age group?", Kevin showed that there was not a significant difference between before and after the taper was in sight for older drivers but there was significant difference between speeds of older and younger drivers at transition taper. Besides, he showed that age is a significant factor for speeds at variable message sign, static sign, taper and activity area of a work zone.Table 1.1 shows results of this study.

Table 2.1 Age as a Factor at Different Locations in a Work Zone

Test	Other	Older	Difference	# of Vehicles	$T_{calculated}$	Significant[a]
Age (At VMS)	66.7	60.3	6.4	100	5.21	Yes
Age (At Static Signs)	66.4	62.9	3.5	100	3.22	Yes
Age (At Static Signs)	65.2	62.9	2.3	112	1.663	No
Age (At Taper)	64.6	58.3	6.3	200	7.67	Yes
Age (At Activity area)	60.0	52.4	7.6	200	13.19	Yes

(Source: Kevin et al, 2009)

2.4 Work Zone Capacity

Work zones tend to reduce capacity of a highway. HCM (Highway Capacity Manual 2000) provides following capacities in a long term zone in as shown in Table 2.2. For short term work zone capacity, HCM provides a capacity of 1600 pc/h/lane. However, this capacity needs to be adjusted for intensity of work activity (not more than 10%), effect of heavy vehicles, and presence of ramps. Capacity for short term work zones thus is given by following equation in HCM 2010.

$Ca= \{[(1600+I)f_{HV}]N\}-R$

Where:

Ca = Adjusted mainline capacity (V/hr)

I= Adjustment factor for type, intensity, and proximity of work activity (pc/hr/ln)

f_{HV} = Heavy vehicle adjustment factor

N = Number of lanes open through work zone

R = Manual adjustment for on-ramps (V/hr)

Table 2.2 HCM Capacities for Long Term Work Zone

No. of normal lanes	Lanes open	Number of studies	Range of values (Veh/h/ln)	Ave per lane (Veh/h/ln)
3	2	7	1780-2060	1860
2	1	3	-	1550

Kevin (2007) provided a summary for work zone capacities obtained from different studies. The summary is provided in table 2.3.

Table 2.3 Summary of Capacities from Different Studies

Study	**Capacity Estimate**
Krammes and Lopez (1999)	1600 pcphl (Short term WZ)
Maze et al (1999)	1374 to 1630 pcphl
Maze et al(2000)	1400 to 1600 pcphl
Sarasua et al. (2004)	1460 pcphl (Short term WZ)
Al- Kaisy et al. (2000)	1600 pcphl
Al-Kaisy and Hall (2003)	1853 and 2252 pcphl (Short term WZ)
Ping and Zhu (2006)	1320 to 1920 pcphl (looking for some more)

Source: Kevin et al, 2007

Kevin in the same study provided different factors for different drivers attributes to find work zone capacity. These factors are given in Table 2.4.

Table 2.4 Reduction Factor for Capacity

Familiarity	Adaptability	Familiarity Factor
High	High	1.25
High	Medium	1.1
High	Low	1.0
Medium	High	1.0
Medium	Medium	.9
Medium	Low	.8
Low	High	.95
Low	Medium	.9
Low	Low	.8

Aggressiveness	Accommodation	Behavior Factor
High	High	1.0
High	Medium	.9
High	Low	.8
Medium	High	1.1
Medium	Medium	1.0
Medium	Low	.9
Low	High	.9
Low	Medium	.85
Low	Low	.8

Source: Kevin et al, 2007

Benekohal et al (2010) suggested capacities for work zones for different traffic conditions as shown in Table 2.5.

Table 2.5 Work zone Capacities for Different Traffic Conditions

Traffic Condition	**Capacities (pcphpl)**
Flagger, queue, SL=45 (SL: Speed Limit)	1200
Low work activity, flagger, dynamic speed feedback sign no queue, SL=45	1400
No work activity ,no queue, SL=45	1550
Police, no work activity, no queue, SL=45	1450
Dynamic speed feedback sign no work activity , no queue, SL=55	1600
Short distance work zone, no work activity, no queue, SL=55	1750
No work activity, no queue, SL=55	1700

Source: Benekohal et al, 2010

In Summary it can be concluded that Work zone acts like a bottle neck and tend to reduce the capacity of highway and if the volume is high, it can cause queuing. Major factors that affect capacity of highway in a work zone are intensity of activity and percentage of heavy vehicles.

CHAPTER 3

METHODOLGY FOR DATA COLLECTION

Chapter 3 describes in detail the objective and the methodology of data collection.

3.1 Objective

As the research is about having an insight into driver's response, the ideal way that comes to mind is to setup all possible setting in a real world environment to measure such response or to design an experiment which would provide statistically meaningful results. However, a large scale multi-year real world data collection plan is not possible for a student writing an MS thesis.

To compare driving conditions in the US and Pakistan, it is essential that drivers know them both and have driving experience in the US and Pakistan. This makes it even more difficult to conduct a real world experiment in Urbana-Champaign with a handsome number of samples as there is a very limited number of Pakistanis who either live here permanently or have come here for studies. The number is further limited by the fact that participants should have US driver's license.

With the above constraints in view, it is decided that a survey be conducted to measure driver's response to reduction in taper length on a highway work zone given that the survey provides a clear description of the highway work zone situations.

3.2 Data Collection

To collect data on drivers' perception of comfort level to see if there is a reduction in taper length, a questionnaire was designed for the web-based survey.

3.2.1 Questionnaire Development

The questionnaire is designed keeping in view the thesis requirements. Questions were designed so as to keep the participant's identity anonymous. For personal question, the answer choices for age, residence etc were designed in a way that participant would not need give a specific reply and thus would not feel uncomfortable. In addition, for good understanding of participant, questions were accompanied by schematics of transition area. Final questionnaire was designed after corrections in a series of draft questionnaires.

3.2.2. Institutional Requirements

Since the survey involves human subjects, Institutional Review Board of the University requires the researcher to know all ethical and professional aspects of such research. Following mandatory trainings modules are completed in order to get approval from Institutional review board of the university.

Belmont Report and CITI Course Introduction

History and Ethical Principles – SBR

Defining Research with Human Subjects – SBR

Informed Consent – SBR

3.2.3. Pre-Testing

Once developed, the questionnaire was distributed among 10 Pakistanis in Urbana-Champaign. They were asked to fill the survey and provide their feed-back about any confusion that they faced while replying to the questions in the survey. The feed-back was then taken to make minor changes in the questionnaire.

3.2.4 Survey Distribution

Google survey is used to develop the survey and record the responses. The peculiar nature of survey requires only participants who have experience both in the US and Pakistan; In other words the Pakistanis living in the US. This makes the total eligible population pretty limited. Initially, it was expected that about 200-250 responses would be collected. Online survey link was e-mailed to prospective participants. For this purpose, different Pakistani organizations, student associations, Pakistani embassy and consulates were contacted. The rate of return cannot be estimated since in most of the cases the organization and associations are contacted instead of individuals. Follow up e-mails were also sent to remind participants to complete and return the survey. Data was collected from Jan 2011 to Feb 2011. Finally, 108 completed surveys were received.

3.2.5 Content of Questionnaire

The survey questionnaire consists of three parts. First part is about general demographics. Second part is related to driver's perception about reduction in taper length on a motorway. Third part is about driver's perception about reduction in taper length on a highway. Questions are accompanied with schematic diagrams to facilitate participants imagine the difference in standard MUTCD taper length in comparison to reduction. (See Appendix-I)

Part 1 asks the respondents about their sex, age group, driving experience, work zone experience and whether they had any accident while travelling through work zones.

Respondents were provided 7 options for age group. This was done to have a closer idea of the respondent's age while not asking their real age. Therefore age was a categorical variable. However, experiences were asked in terms of number of years. Thus the outcome variable is a continuous one.

The questions in part two and three provided a Likert scale for response to reductions in taper length in a work zone on a motorway. The scale consists of five stages from very comfortable to very uncomfortable. The resulting variable is ordinal.

CHAPTER 4

DATA ANALYSIS LEVEL-I

A total of 108 responses were collected. The responses are of diverse nature in terms of residency, age and experience.

4.1 Demographics and Experiences

This section contains details of responses obtained for Part-I of the survey.

4.1.1 Gender

Out of a total of 108 survey participants, only 3 were females. This was expected since the number of female drivers in Pakistan is also very low. Correct number of female drivers in Pakistan is not known because the driver's license issuing is not computerized and there is no central data base for drivers in Pakistan. Number of female drivers is higher in urban areas as compared to rural areas.

4.1.2 Home Province in Pakistan

The participants were asked the following question.

In which province of Pakistan do you reside?

Table 4.1 provides a comparison between percent of population and percent of responses to the survey by provinces. Fig 4.1 shows the map of Pakistan. The survey respondents provided a proportionate representation of population distribution of provinces in Pakistan.

4.1.3 Resident State in the US

People from 26 states participated in survey. The majority of respondents came from Illinois (25%),Texas (18%) and Georgia (9%).

Table 4.1 Province –Wise Population and Responses

Province	Population (in Millions)	% Population	Number of Responses	%Responses
Punjab	96.55	54.0	55	50.9
Sindh	42.18	23.6	25	23.1
Khyber Pakhtunkhwa	27.97	15.6	5	4.6
Balochistan	9.07	5.1	7	6.5
GilgitBaltistan	1.8	1.0	2	1.9
Islamabad	1.33	0.7	11	10.2
Not Specified			3	2.8
Total	178.9	100	108	100

Fig 4.1 Map of Pakistan

Other than Table 4.2, California and Pennsylvania recorded 3 responses each, New Jersey, Oklahoma, Oregon and Washington recorded 2 responses each. Remaining 13 states provided only 1 response. It can be seen from table 4.2 that responses from different states are not proportionate to the population of respective state, and this is not expected due to the following reasons:

a- Pakistanis are not proportionately distributed in the US.

b- Survey was not sent to all Pakistanis living in the US.

The responses are coming from a wide variety of states and they represent various climate and roadway conditions in the US. This diverse representation is desirable because it represents different driving conditions in the US.

Table 4.2 State-wise Percent Responses

State	Population	% of US Population	Responses	% Responses
Illinois	12,830,632	4.1	26	24.8
Texas	25,145,561	8.0	19	18.1
Georgia	9,687,653	3.1	9	8.6
Virginia	8,001,024	2.6	8	7.6
Indiana	6,483,802	2.1	6	5.7
Florida	18,801,310	6.0	5	4.8
Maryland	5,773,552	1.9	5	4.8

4.1.4 Age

Age is a major factor that has to be considered as described in Section 2.3. The respondents are from all 7 age groups. Table 4.3 provides the number of participants in each age group. The majority (75.7%) of the participants belong to 26-35 and 36-45 years categories. This is because most of the participants are young Pakistani professionals or graduate students.

4.1.5 Pakistani Driver’s License and Experiences

The participants were asked:

a- Do you have a Pakistani driver’s license?

b- If yes, how long have you had a Pakistani driver's license?

c- Have you driven through a work zone in Pakistan?

Table 4.3 Age Groups

Age	Frequency	Percent
<20 years	4	3.74
21-25 years	8	7.48
26-35 years	56	52.34
36-45 years	25	23.36
46-55 years	7	6.54
56-65 years	5	4.67
>65 years	2	1.87

Out of 108 responses, 24 participants (22%) did not have Pakistani driver's license. However, only 12 (11%) did not have experience of driving through work zone on a highway or motorway and 10 respondents were common among the two groups (i.e those who did not have license and those who did not have driving experience through work zone). Out of remaining 14 respondents who did not have Pakistani driver's license, 3 responded that they did not get their licenses renewed. It cannot be ascertained if remaining 11 respondents drove without driver's license or they too had not renewed their licenses since the question did not specifically ask about validity of license.

There is a wide range for years of driving experience with maximum and minimum being 46 years and 0. Table 4.4 shows number of years of driving experience in Pakistan and US as reported by the respondents. Out of total of 108 respondents, 94% of the people never had an accident while passing through a work zone in Pakistan.

4.1.6 US Driver's License and Experiences

Out of 108 responses, 7 participants (6 %) did not have US driver's license and only 4 (3%) did not have experience of driving through work zone on a highway or freeway. There is a wide range for years of driving experience in US with maximum being 40 years and minimum 0. About 96% of the people never had an accident while passing through a work zone in the US. Table 4.4 shows the number of years of driving experience of participants in the US.

Table 4.4 Driving Experience in Pakistan and US

Driving experience in Pakistan			Driving experience in US		
Pak-Exp (Years)	Frequency	Percent	US-Exp (Years)	Frequency	Percent
0	20	19.05	0	7	6.48
1	1	0.95	0.5	2	1.85
3	1	0.95	1	12	11.11
4	1	0.95	1.5	3	2.78
5	7	6.67	2	11	10.19
6	2	1.9	2.5	1	0.93
7	4	3.81	3	10	9.26
7.5	1	0.95	3.5	1	0.93
8	6	5.71	4	15	13.89
9	2	1.9	5	4	3.7
10	17	16.19	6	8	7.41
11	1	0.95	7	5	4.63
12	5	4.76	8	1	0.93
13	1	0.95	9	1	0.93
14	3	2.86	10	5	4.63
15	9	8.57	12	7	6.48
16	1	0.95	15	1	0.93
17	2	1.9	17	3	2.78
18	1	0.95	20	3	2.78
19	1	0.95	23	1	0.93
20	7	6.67	25	2	1.85
22	1	0.95	28	1	0.93
25	5	4.76	30	1	0.93
26	1	0.95	39	1	0.93
32	1	0.95	40	2	1.85
35	1	0.95	Total	108	100
40	2	1.9	*Arranged in the ascending order of number of years of experience * 3 Frequencies are unspecified for Pakistani experience.		
46	1	0.95			
Total	105	100			

4.2 Data Filtration

The survey was conducted from January 1 to February 15, 2011. A total of 108 responses were received. Out of these total responses, 24 reported that they did not have Pakistani driver's license and 7 reported that they did not have US driver's license. Participants who did not have US driver's license were excluded from analysis (5 left the reply space blank, one of them had applied for it, and had learner's permit). However, all of the participants who did not have Pakistani driver's license had US license. Participants who did not have Pakistani driver's license but had experience of driving through work zone in Pakistan, are included for final analysis.

Different reduction levels on highways and motorways are treated as response variables. Table 4.5 gives a list of such variable. These variables will be represented by their symbols later in this literature.

Table 4.5 Symbols

Reduction level	Motorways	Highways	Taper length(ft) (Motor/Highway)
No Reduction	MR00	HR00	900/675
10%	MR10	HR10	810/610
20%	MR20	HR20	720/540
30%	MR30	HR30	630/470
40%	MR40	HR40	540/410

Another filter that is applied is based on the fact that reduction in taper length should cause the comfort level either to reduce or to remain at least the same, and comfort level should not increase with the reduction in taper length. This inconsistency was treated as hints towards either careless filling out of the survey or misunderstanding or misinterpretation of the survey content. Hence a decision is made that surveys with only one such inconsistency are to be included for analysis to allow for some casual mistake.

There were 8 inconsistent replies and out of remaining 100 replies 6 did not have US license and 11 did not have driving experience through a work zone. This means that there is no overlap between participants who did not have US driver's license and people who did not have driving experience through a work zone in Pakistan. After excluding these observations the total number of responses that are left for analysis is 83.

4.3 Average Comfort Level

Part 2 and 3 of survey asked about driver's perception if the taper length is gradually decreased. Respondents were provided Likert scale to record the responses. Following are the questions asked.

a- "In the U.S, for a freeway approach speed of 120kph (about 75 mph), standard taper length is "X" ft. Indicate your comfort level while going through a work zone with standard taper length? (No reduction in taper length)."

OR for highways

"In the U.S, for a highway approach speed of 90kph (about 56 mph), standard taper length is "X" ft. Indicate your comfort level while going through a work zone with standard taper length? (No reduction in taper length)."

b- "Imagine you are driving on a Pakistani Motorway at speed of 120kph (about 75 mph), indicate your comfort level if the taper length is reduced to "Y" ft".

OR for highways

"Imagine you are driving on a Pakistani Highway at speed of 90kph (about 56 Mph), indicate your comfort level if the taper length is reduced to "Y" ft".

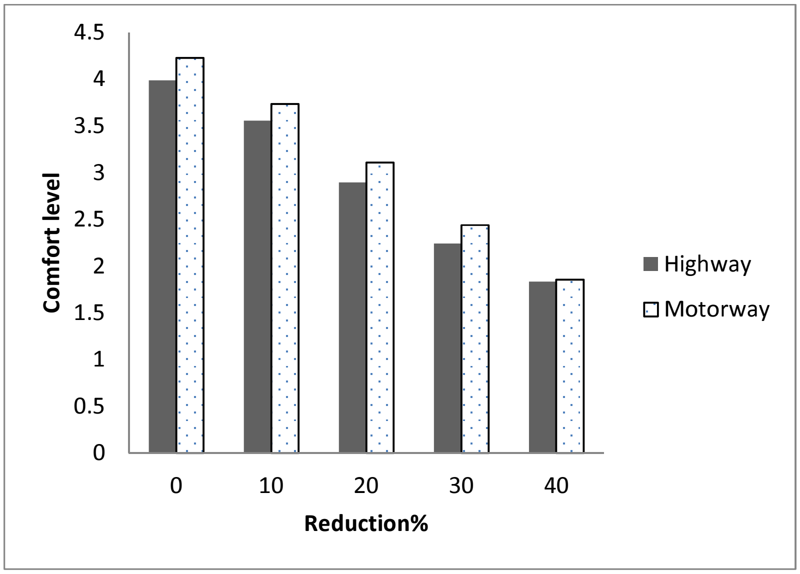
For the sake of analysis the comfort levels are given numeric values as following.

Very comfortable	5
Somewhat Comfortable	4
Neither comfortable nor uncomfortable	3
Somewhat Uncomfortable	2

Very uncomfortable 1

For each level of reduction, the average comfort level was calculated based on the responses from 83 participants. Fig 4.2 suggests that for any level of reduction in taper length, mean comfort level on motorway is numerically higher than that of the highway.

Fig 4.2 Reduction Level Vs Comfort Level



However, statistical tests were conducted to determine if the means for motorways are significantly higher than those for highways. It is further observed that the data for each level of reduction (comfort levels in numeric terms) is not normal. Therefore, both parametric and non-parametric statistical test are conducted. Table 4.6 provides the results for t-test and Wilcoxon Rank Sum test (t-test equivalent for non-parametric analysis).

The results show that both t-test and Wilcoxon Rank Sum test give almost the same results as indicated by the very similar p-value (probability values). However, Wilcoxon Rank Sum test is more reliable in this case as the data is non-normal. According to Wilcoxon Rank Sum test results, for alpha=10%, means for motorway are greater than means for highways for “no reduction” and 20% reduction. However, probability values for 10% and 20% reduction level are also very close to 0.1. Thus it can be concluded that means for motorway are greater than means for highways for reduction levels up to 30%.

Table 4.6 Test Results for Means

Variable	Mean	Standard deviation	Reduction Level	P-Value T-Test	Sum Of Ranks	P-Value Wilcoxon Rank sum
MR00	4.2289157	0.9793639	No Reduction	0.0722	7298	0.0763
HR00	3.9878049	1.1275879			6397	
MR10	3.7349398	1.0941567	10%	0.1434	7291	0.1110
HR10	3.5542169	1.0848515			6570	
MR20	3.1084337	1.0821393	20%	0.0945	7322.50	0.0945
HR20	2.8915663	1.0360814			6538.50	
MR30	2.4390244	1.0783797	30%	0.1083	7140.50	0.1271
HR30	2.2409639	0.9701692			6554.50	
MR40	1.8554217	1.0137173	40%	0.4364	6896.50	0.4537
HR40	1.8313253	0.921548			6964.50	

Distribution of differences between comfort levels on motorways and highways for each participant is shown in Fig 4.3. It can be seen that the distribution of differences is concentrated around zero with a slight tilt toward positive values.

For each level of reduction, a paired t-test was conducted to see if the average of the differences is greater than zero. The results are shown in Table 4.7. The result show that comfort level for motorways is higher than for highways for “No reduction”, 20 and 30% reductions. For 10% reduction P-value is 0.1041 which is very close to 0.1. Hence it can be concluded that for reduction level up to 30%, difference between comfort level for motorways and highways is greater than 0.

4.4 Discussion

It can be seen from Table 4.5 that the highest reduction level for which the average comfort level is above 3 (Neither comfortable nor uncomfortable) for both motorways and highways is 10%. However, for average value of comfort level for 20% reduction for highways is very close to 3 (2.89) and still above 3 for motorways (3.10). This indicates a maximum reduction of 20% implying that further decrease would lead to comfort level well below 3.

Difference in comfort level on motorways and highways is significant for reduction level up to 30% and a further decrease by 10% in taper length leads to indifference between motorways and highways by the driver.

Fig 4.3 Distribution for Differences between Comfort Level for Motorways and Highways

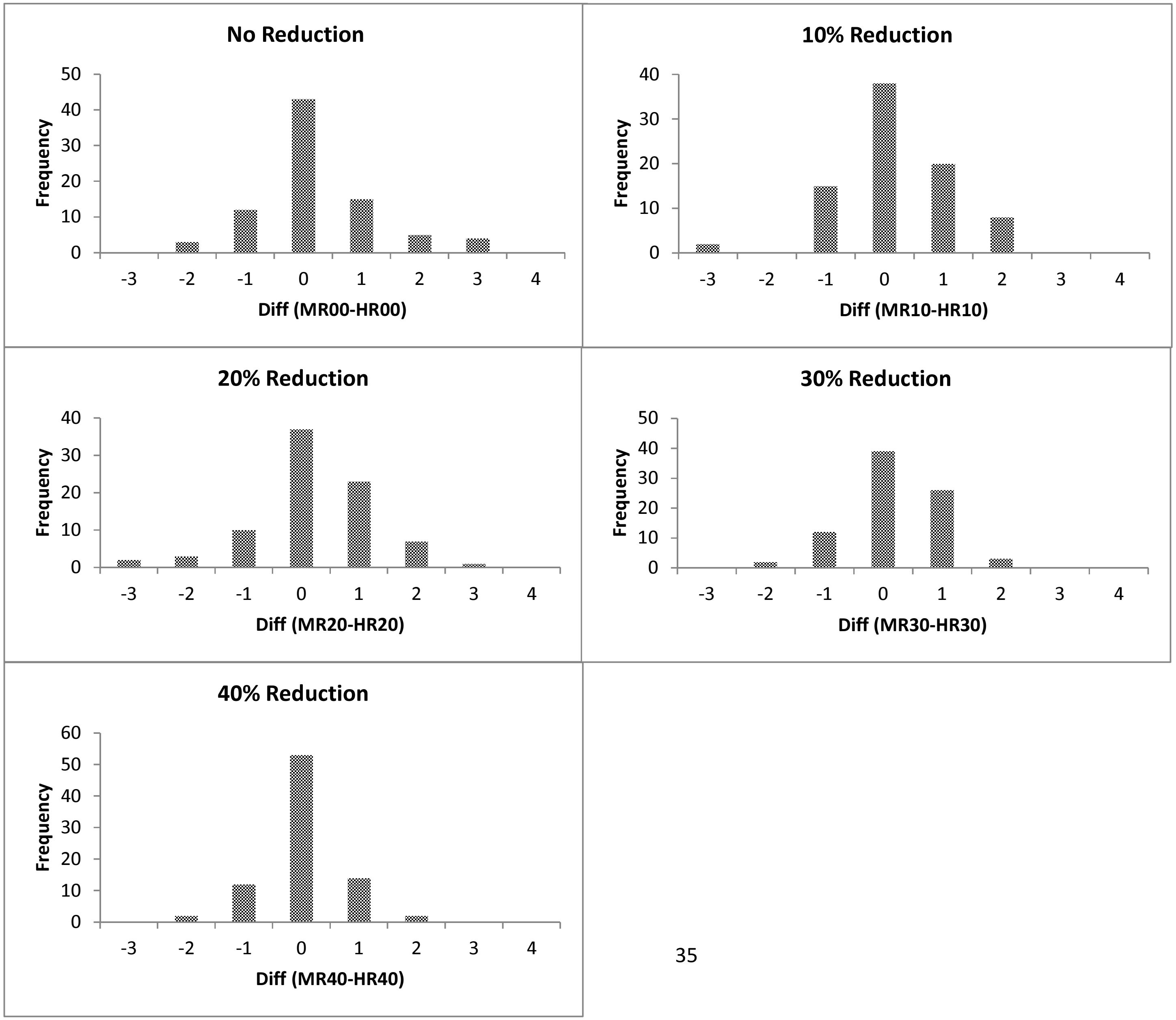


Table 4.7 Results for Paired Data

Variable	Mean of Differences	Standard deviation	Reduction Level	P-Value Paired T-Test
MR00 HR00	0.2317	1.0576	No Reduction	0.0506
MR10 HR10	0.1807	1.0018	10%	0.1041
MR20 HR20	0.2168	1.0825	20%	0.0716
MR30 HR30	0.1951	0.8231	30%	0.0348
MR40 HR40	0.02409	0.7153	40%	0.7597

CHAPTER 5

LEVEL-II ANALYSIS

In Chapter 4, frequency of responses for different questions in the survey was discussed. Chapter 5 will analyze the respondents comfort level for different levels of reduction with respect to different driver's characteristics.

5.1 Statistical Test

The objective of the analysis is to look for potential relationship between independent variables such as age, experiences etc and dependent variable (comfort level at a given reduction level). The appropriate statistical test for this purpose is chi square goodness of fit test. However, due to small data set this test could not be applied. Chi square test requires that the theoretical frequency for each cell be at least 5 in order to give adequate approximation. Hence it is decided to use Fisher's exact test for the analysis. Fisher's exact test is more robust and gives exact values for probabilities especially for small data set as compared to Chi-Square test. Although Fisher's exact test was used for determining probabilities, Chi-Square tables were also useful to find various trends in data. The test has the null hypothesis that variables are consistent with a specified distribution. H_o is tested at alpha level of 10% i.e. at P-value less than 0.1, the null is rejected and it is concluded that response variable has the same distribution as expected.

5.2 Analysis of Interdependence

It is usually perceived that different driver characteristics such as age, driving experience etc influence driver's response to a particular situation on roadway. Sections 5.3 to 5.8 deal with analysis of dependence of driver's response on his/her characteristics.

5.3 Age Vs Taper Length Reduction

Data could not be analyzed with 7 age groups due to lack of enough sample in each category. For 7 age groups, 5 comfort levels (Chi square table had 35 cells) and with only 83 observations of filtered data set reasonable trends could not be obtained. It is therefore decided to combine the age categories of “below 20 years” and “21-25 years” and designate it as “below 25 years” on one hand, and to combine “above 65 years” and “56-65 years” and designate it as “above 55 years” on the other hand. Besides, 5 comfort levels were reduced to 3 comfort levels by combining “very comfortable” and “somewhat comfortable” and designating it as “comfortable” (or 3 in numeric terms) on one hand and by combining “Very uncomfortable” and “somewhat uncomfortable” and designating it as “uncomfortable” (or 1 in numeric terms), on the other hand. The comfort level designated as “neither comfortable nor uncomfortable” (2 in numeric terms) was not changed. Table 5.1 shows frequency of filtered data with original and modified age groups.

Table 5.1 Modified Age Groups

Ag	Frequency (years)	Percent	Modified age	Frequency (years)
<2	2	2.4	<25	6
21	4	4.8		
26	47	56.6	26-35	47
36	19	22.9	36-45	19
46	6	7.2	46-55	6
56	4	4.8	>55	5
>6	1	1.2		

Modified age categories were tested for significance against different levels of reduction.

5.3.1 Age and Different Reduction Levels on Motorways

Age was found to be a significant factor for 20 and 30% reduction on Motorways. Table 5.2 provides the probability values. Sub sections 5.3.1.1 to 5.3.1.5 describe the finding for different levels of reduction.

Table 5.2 Probability Values for Age vs Reduction for Motorways

Reductions	Fisher's Test P-Value	Chi Square Test		
		D.F	Chi Sq Value	P-Value
No Reduction	0.2419	8	7.2487	0.5101
10%	0.349	8	7.0294	0.5335
20%	0.0702	8	14.0728	0.0799
30%	0.033	8	15.6067	0.0484
40%	0.1077	8	14.3638	0.0728

5.3.1.1 No Reduction on Motorways

Age is not a significant factor with Fisher's P-Value=0.2419. As expected, no age group is significantly under or overrepresented in the three comfort levels as shown in Table 5.3. The table indicates that a great majority of the participants feel comfortable with no reduction.

Table 5.3 Chi Square for Age and "No Reduction level" on Motorways

Table of Age by MR00				
Age (Years)	**Comfort Level**			
Frequency Expected Cell Chi-Square	**1**	**2**	**3**	**Total**
25or<	0 0.4337 0.4337	1 1.012 0.0001	5 4.5542 0.0436	6
26-35	1 3.3976 1.6919	7 7.9277 0.1086	39 35.675 0.31	47
36-45	3 1.3735 1.9261	4 3.2048 0.1973	12 14.422 0.4066	19
46-55	1 0.4337 0.7393	1 1.012 0.0001	4 4.5542 0.0674	6
55or>	1 0.3614 1.1281	1 0.8434 0.0291	3 3.7952 0.1666	5
Total	6	14	63	83

5.3.1.2 10% Reduction on Motorways

Age is not a significant factor for 10% reduction in taper length on motorways according to Fisher's test with a P-value of 0.349. There is no significant under or over representation of age versus comfort level. Table 5.4 gives the actual and expected frequencies for all age groups.

Table 5.4 Chi Square for Age and "10% Reduction level" on Motorways

Table of Age by MR10				
Age (Years)	**Comfort Levels**			
Frequency Expected Cell Chi-Square	**1**	**2**	**3**	**Total**
25or<	1 0.8675 0.0202	1 1.0843 0.0066	4 4.0482 0.0006	6
26-35	4 6.7952 1.1498	8 8.494 0.0287	35 31.711 0.3412	47
36-45	4 2.747 0.5715	4 3.4337 0.0934	11 12.819 0.2582	19
46-55	2 0.8675 1.4786	0 1.0843 1.0843	4 4.0482 0.0006	6
55or>	1 0.7229 0.1062	2 0.9036 1.3303	2 3.3735 0.5592	5
Total	12	15	56	83

5.3.1.3 20% Reduction on Motorways

Age is a significant factor for 20% reduction in taper length on motorways according to Fisher's test with a P-value of 0.0702. Table 5.5 shows that for the age groups 36-45 years and "55 years or above", participants are over-represented in uncomfortable zone. Besides, participants are under-represented in comfortable zone for age category 36-45 years and underrepresented in uncomfortable zone for age category 25 years or less.

Table 5.5 Chi Square for Age and 20% Reduction level on Motorway

Table of Age by MR20				
Age (Years)	**Comfort Levels**			
Frequency Expected Cell Chi-Square	**1**	**2**	**3**	**Total**
25or<	0 1.8795 1.8795	2 1.5904 0.1055	4 2.5301 0.8539	6
26-35	11 14.723 0.9414	13 12.458 0.0236	23 19.819 0.5105	47
36-45	9 5.9518 1.5611	6 5.0361 0.1845	4 8.012 2.009	19
46-55	2 1.8795 0.0077	1 1.5904 0.2191	3 2.5301 0.0873	6
55or>	4 1.5663 3.7816	0 1.3253 1.3253	1 2.1084 0.5827	5
Total	26	22	35	83

5.3.1.4 30% Reduction on Motorways

Age is a significant factor for 30% reduction in taper length on motorways with Fisher test P-value of 0.033. Table 5.6 shows that for the age group 25 years or less and 26-35 years, participants are under-represented in uncomfortable zone and the participants from age group 36-45 years and “55 years or greater” are over-represented in uncomfortable category. Participants from age category 36-45 years are underrepresented in comfortable zone. The trend in the Table 5.6 can be observed that younger people are under-represented while middle aged and older people are over represented in the uncomfortable zone.

Table 5.6 Chi Square for Age and 30% Reduction level on Motorway

Table of Age by MR30				
Age (Years)	**Comfort Levels**			
Frequency Expected Cell Chi-Square	**1**	**2**	**3**	**Total**
25or<	1 2.8659 1.2148	2 1.1585 0.6112	2 0.9756 1.0756	5
26-35	21 26.939 1.3093	14 10.89 0.888	12 9.1707 0.8729	47
36-45	16 10.89 2.3975	2 4.4024 1.311	1 3.7073 1.9771	19
46-55	4 3.439 0.0915	1 1.3902 0.1095	1 1.1707 0.0249	6
55or>	5 2.8659 1.5893	0 1.1585 1.1585	0 0.9756 0.9756	5
Total	47	19	16	82
Frequency Missing = 1				

5.3.1.5 40% Reduction on Motorways

P-value for 40% reduction on motorways is 0.1077. With alpha=10%, this P-value is considered to suggest that age is not a significant factor.

Table 5.7 Chi Square for Age and 40% Reduction level on Motorway

Table of Age by MR40				
Age (Years)	**Comfort Levels**			
Frequency Expected Cell Chi-Square	**1**	**2**	**3**	**Total**
25or<	4 4.4096 0.0381	0 1.1566 1.1566	2 0.4337 5.656	6
26-35	31 34.542 0.3632	13 9.0602 1.7132	3 3.3976 0.0465	47
36-45	17 13.964 0.6601	2 3.6627 0.7548	0 1.3735 1.3735	19
46-55	4 4.4096 0.0381	1 1.1566 0.0212	1 0.4337 0.7393	6
55or>	5 3.6747 0.478	0 0.9639 0.9639	0 0.3614 0.3614	5
Total	61	16	6	83

5.3.2 Age and Different Reduction Levels on Highways

For highways, age is not a significant factor except for 10% reduction level where the P-value is 0.026. Table 5.8 provides the probability values. Sub sections 5.3.2.1 to 5.3.2.5 describe the finding for different levels of reduction.

Table 5.8 Probability Values for Age vs Reduction for Highways

Reductions	Fisher's Test P-Value	Chi Square Test		
		D.F	Chi Sq Value	P-Value
No Reduction	0.677	8	4.9692	0.7609
10%	0.0276	8	15.3734	0.0523
20%	0.626	8	6.4767	0.594
30%	0.3378	8	7.3037	0.5043
40%	0.3414	8	8.4428	0.3915

5.3.2.1 No Reduction on Highways

Age is not a significant factor at “no reduction” in taper length on highway. P-value from Fisher’s exact test is 0.677. Table 5.9 provides actual and expected frequencies. It can be seen in the table that actual and expected frequencies are nearly equal for all cells of the table and there is no significant under or over representation of any age group.

Table 5.9 Chi Square for Age and No Reduction level on Highways

Table of Age by HR00				
Age (Years)	**Comfort Levels**			
Frequency Expected Cell Chi-Square	**1**	**2**	**3**	**Total**
25or<	0 0.8049 0.8049	2 0.7317 2.1984	4 4.4634 0.0481	6
26-35	6 6.1707 0.0047	4 5.6098 0.4619	36 34.22 0.0926	46
36-45	3 2.5488 0.0799	3 2.3171 0.2013	13 14.134 0.091	19
46-55	1 0.8049 0.0473	1 0.7317 0.0984	4 4.4634 0.0481	6
55or>	1 0.6707 0.1616	0 0.6098 0.6098	4 3.7195 0.0212	5
Total	11	10	61	82
Frequency Missing = 1				

5.3.2.2 10% Reduction on Highways

Age is a significant factor for 10% reduction in taper length on Highways with Fisher test P-value of 0.0276. Chi square table (Table 5.10) shows that age group 26-35 is under represented whereas age groups 36-45 and 46-55 years are over represented in uncomfortable zone. Further, age group 26-35 years is over represented and participants from age category 36-45 years is underrepresented in comfort level 2

Table 5.10 Chi Square for Age and 10% Reduction level on Highway

Table of Age by HR10				
Age (Years)	**Comfort Levels**			
Frequency Expected Cell Chi-Square	**1**	**2**	**3**	**Total**
25or<	1 0.9398 0.0039	2 1.5181 0.153	3 3.5422 0.083	6
26-35	3 7.3614 2.584	16 11.892 1.4194	28 27.747 0.0023	47
36-45	7 2.9759 5.4415	1 4.8072 3.0152	11 11.217 0.0042	19
46-55	2 0.9398 1.1962	1 1.5181 0.1768	3 3.5422 0.083	6
55or>	0 0.7831 0.7831	1 1.2651 0.0555	4 2.9518 0.3722	5
Total	13	21	49	83

5.3.2.3 20% Reduction on Highways

Age is not a significant factor for comfort level at 20% reduction in taper length with Fisher exact test P-value=0.626. No under or over representation for any age group is observed as shown in Table 5.11.

Table 5.11 Chi Square for Age and 20% Reduction level on Highway

Table of Age by HR20				
Age (Years)	**Comfort Levels**			
Frequency Expected Cell Chi-Square	**1**	**2**	**3**	**Total**
25or<	3 2.1687 0.3187	2 1.9518 0.0012	1 1.8795 0.4116	6
26-35	14 16.988 0.5255	16 15.289 0.033	17 14.723 0.3522	47
36-45	10 6.8675 1.4289	6 6.1807 0.0053	3 5.9518 1.464	19
46-55	2 2.1687 0.0131	2 1.9518 0.0012	2 1.8795 0.0077	6
55or>	1 1.8072 0.3606	1 1.6265 0.2413	3 1.5663 1.3124	5
Total	30	27	26	83

5.3.2.4 30% Reduction on Highways

Age is not a significant factor at 30% reduction level (P-value=0.3378). No specific trend is observed in Chi square table (Table 5.12).

Table 5.12 Chi Square for Age and 30% Reduction level on Highway

Table of Age by HR30				
Age (Years)	**Comfort Levels**			
Frequency Expected Cell Chi-Square	**1**	**2**	**3**	**Total**
25or<	4 3.9759 0.0001	1 1.3012 0.0697	1 0.7229 0.1062	6
26-35	27 31.145 0.5515	13 10.193 0.7731	7 5.6627 0.3158	47
36-45	16 12.59 0.9234	3 4.1205 0.3047	0 2.2892 2.2892	19
46-55	5 3.9759 0.2638	0 1.3012 1.3012	1 0.7229 0.1062	6
55or>	3 3.3133 0.0296	1 1.0843 0.0066	1 0.6024 0.2624	5
Total	55	18	10	83

5.3.2.5 40% Reduction on Highways

Age is not a significant factor at 40% reduction level (P-value = 0.3414). As shown in Table 5.13. No over or under representation of age groups is observed for any level of comfort.

Table 5.13 Chi Square for Age and 40% Reduction level on Highway

Table of Age by HR40				
Age (Years)	**Comfort Levels**			
Frequency Expected Cell Chi-Square	**1**	**2**	**3**	**Total**
25or<	4 4.8434 0.1469	1 0.7952 0.0528	1 0.3614 1.1281	6
26-35	35 37.94 0.2278	9 6.2289 1.2328	3 2.8313 0.01	47
36-45	18 15.337 0.4623	1 2.5181 0.9152	0 1.1446 1.1446	19
46-55	5 4.8434 0.0051	0 0.7952 0.7952	1 0.3614 1.1281	6
55or>	5 4.0361 0.2302	0 0.6627 0.6627	0 0.3012 0.3012	5
Total	67	11	5	83

5.3.3 Level III Analysis for Age Vs Reduction Level

Level III analysis is done for motorways only, keeping in view the fact that age was a significant factor only for motorways. Figures 5.1 and 5.2 show relative frequency for age with different level of reduction and comfort in two different ways. As discussed in Sec 5.3.1, it can be seen in Fig 5.1 and 5.2 as well that the higher age groups are more uncomfortable for any given level of reduction than lower age groups.

5.3.4 Discussion

For motorways, findings in the sections 5.3.2 and 5.3.3 show that age is a significant factor in driver's response to comfort level for 20 and 30% reduction level whereas P-value for 40% reduction is very close to 0.1. In general, older age drivers are over represented in uncomfortable zone for 20, 30 and 40% reduction and younger drivers i.e up to age 35 years are under-represented in uncomfortable zone.

For age reduction up to 20% majority of drivers lies in comfort level 3 and 2. However, this changes for 30% reduction where majority lies in comfort level1. This suggests that reduction between 20 and 30% may be appropriate.

For highways, age is not significant in general (except for 10% reduction) and therefore there is no specific trend in age versus comfort levels.

For highways, for age reduction up to 20% majority of drivers lies in comfort level 3 and 2. However, this changed for 30% reduction where majority lies in comfort level1. This suggests that reduction between 20 and 30% may be appropriate for highways as well.

Fig 5.1 Relative Frequency for Age and Comfort Level for All Reduction Levels

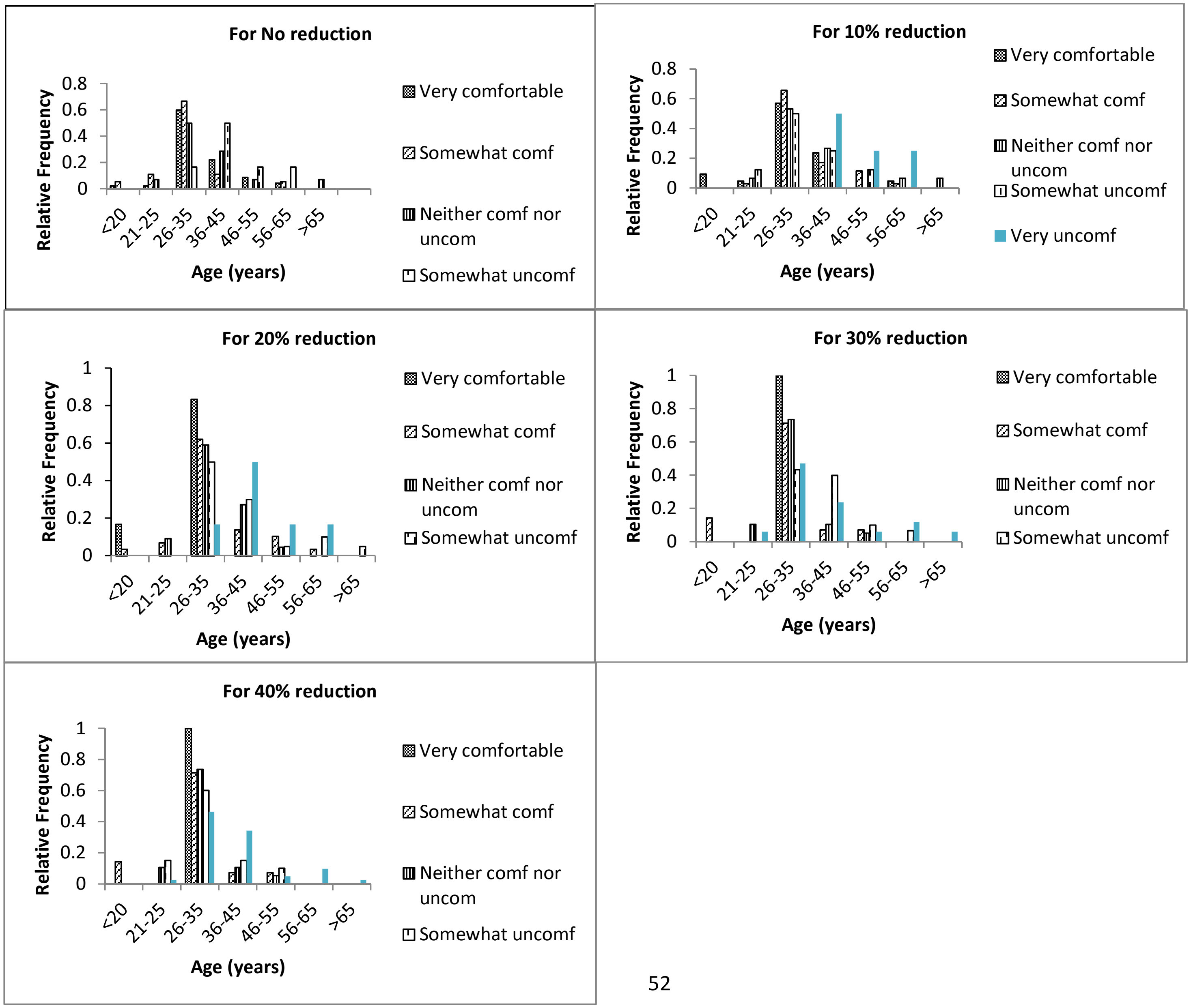
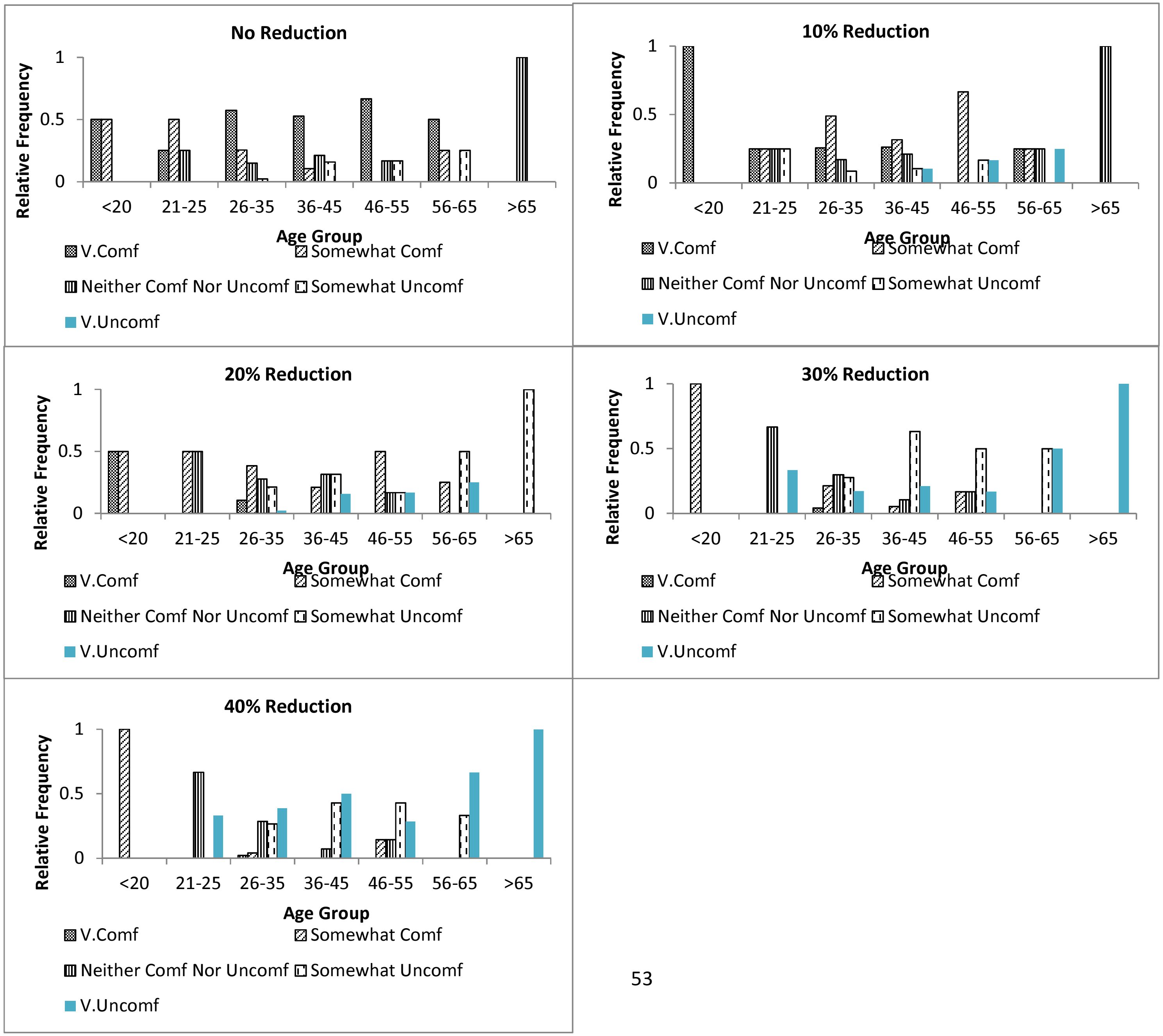


Fig 5.2 Relative Frequency for Age and Comfort Level for All Reduction Levels



5.4 Pakistani Experience Vs Taper Length Reduction

Participants were asked the following question:

a- Do you have a Pakistani driver's license?

b- If yes, how long have you had a Pakistani driver's license?

Pakistani driving experience is a continuous variable having range of experience from 0.5 years to 46 years. Experience is rounded off to nearest 0.5 years. For analysis purpose, experience is divided into categories as shown in Table 5.14. Comfort levels have also been reduced from 5 to 3 by combining upper two and lower two categories as was done in the analysis of age factor.

Table 5.14 Categories for Experience

Categories	Experience	Frequency
Category 1	0 to 1 year	11
Category 2	1 to 5 years	39
Category 3	5 to 10 years	12
Category 4	More than 10 years	21

5.4.1 Pakistani Experience and Different Reduction Levels on Motorways

Driving experience in Pakistan is significant for 30 and 40% reduction levels at alpha=10% Table 5.15 gives probability values.

Table 5.15 Probability Values for Pakistani Experience vs Reduction for Motorways

Reductions	Fisher's Test P-Value	Chi Square Test		
		D.F	Chi Sq Value	P-Value
No Reduction	0.8384	6	3.1897	0.7847
10%	0.5743	6	5.5376	0.4769
20%	0.1083	6	9.0286	0.172
30%	0.0003	6	19.4904	0.0034
40%	0.0964	6	9.095	0.1683

5.4.1.1 No Reduction on Motorways

Pakistani driving experience is not a significant factor at "no reduction". (P-value=0.8384). Actual frequencies are close to expected frequencies as shown in Table 5.16. This is intuitive since at "no reduction" most of people would be comfortable.

Table 5.16 Chi Square for Pakistani Experience and No Reduction level on Motorway

Table of Pak-Exp by MR00				
Pak_Exp	**Comfort Levels**			
Frequency Expected Cell Chi-Square	**1**	**2**	**3**	**Total**
1	0 0.0429 0.0429	0 0.1857 0.1857	1 0.7714 0.0677	1
2	0 0.2143 0.2143	0 0.9286 0.9286	5 3.8571 0.3386	5
3	0 0.5571 0.5571	2 2.4143 0.0711	11 10.029 0.0941	13
4	3 2.1857 0.3034	11 9.4714 0.2467	37 39.343 0.1395	51
Total	3	13	54	70
Frequency Missing = 13				

*Total number of observation for Pakistani experience is less than 83(total for filtered data) because people without Pakistani driver's license are included in data set.

5.4.1.2 10% Reduction on Motorways

Pakistani experience is not a significant factor for 10% reduction in taper length with Fisher Exact test P-Value=0.5743. None of the experience category is over/under-represented as shown in Table 5.17.

Table 5.17 Chi Square for Pakistani Experience and 10% Reduction level on Motorway

Table of Pak-Exp by MR10				
Pak-Exp	**Comfort Levels**			
Frequency Expected Cell Chi-Square	**1**	**2**	**3**	**Total**
1	0 0.1 0.1	0 0.1857 0.1857	1 0.7143 0.1143	1
2	0 0.5 0.5	0 0.9286 0.9286	5 3.5714 0.5714	5
3	0 1.3 1.3	4 2.4143 1.0415	9 9.2857 0.0088	13
4	7 5.1 0.7078	9 9.4714 0.0235	35 36.429 0.056	51
Total	7	13	50	70
Frequency Missing = 13				

5.4.1.3 20% Reduction on Motorways

Pakistani experience is not a significant for 20% reduction in taper length with Fisher Exact test P-Value=0.1083. However, P-value is very close to 0.1 and therefore some trend is expected. Chi square values are given in Table 5.18. It can be seen that actual frequencies are less than expected for experience category 1, 2, and 3 whereas actual frequency is more than expected for experience category 4 in uncomfortable zone.

Table 5.18 Chi Square for Pakistani Experience and 20% Reduction level on Motorway

Table of Pak-Exp by MR20				
Pak-Exp	**Comfort Level**			
Frequency Expected Cell Chi-Square	**1**	**2**	**3**	**Total**
1	0 0.2857 0.2857	1 0.3 1.6333	0 0.4143 0.4143	1
2	0 1.4286 1.4286	2 1.5 0.1667	3 2.0714 0.4163	5
3	1 3.7143 1.9835	5 3.9 0.3103	7 5.3857 0.4839	13
4	19 14.571 1.3459	13 15.3 0.3458	19 21.129 0.2144	51
Total	20	21	29	70*
Frequency Missing = 13				

5.4.1.4 30% Reduction on Motorways

Pakistani experience is highly significant for 30% reduction in taper length with Fisher Exact test P-Value=0.0003. Chi square values (Table 5.19) for Pakistani experience Vs comfort level for 30% reduction in taper length suggest that for experience category 2 and 3 people are underrepresented and people from category 4 are over represented in uncomfortable zone. In comfort level 2, experience category 3 is over represented and category 4 is underrepresented.

Table 5.19 Chi Square for Pakistani Experience and 30% Reduction level on Motorway

Table of Pak-Exp by MR30				
Pak-Exp	**Comfort Levels**			
Frequency Expected Cell Chi-Square	**1**	**2**	**3**	**Total**
1	0 0.5797 0.5797	1 0.2319 2.5444	0 0.1884 0.1884	1
2	1 2.8986 1.2436	2 1.1594 0.6094	2 0.942 1.1882	5
3	2 6.9565 3.5315	6 2.7826 3.7201	4 2.2609 1.3378	12
4	37 29.565 1.8696	7 11.826 1.9695	7 9.6087 0.7082	51
Total	40	16	13	69
Frequency Missing = 14				

5.4.1.5 40% Reduction on Motorways

For 40% reduction, dependence of comfort level on experience is significant at Alpha=0.1 (P-value= 0.0964). It can be seen from the Table 5.20 that experience category 1 is over represented in comfort level 2 and experience category 2 is overrepresented in comfort level 3.

Table 5.20 Chi Square for Pakistani Experience and 40% Reduction level on Motorway

Table of Pak-Exp by MR40				
Pak-Exp	**Comfort Levels**			
Frequency **Expected** **Cell Chi-Square**	**1**	**2**	**3**	**Total**
1	0 0.7429 0.7429	1 0.2143 2.881	0 0.0429 0.0429	1
2	3 3.7143 0.1374	1 1.0714 0.0048	1 0.2143 2.881	5
3	8 9.6571 0.2844	4 2.7857 0.5293	1 0.5571 0.352	13
4	41 37.886 0.256	9 10.929 0.3403	1 2.1857 0.6432	51
Total	52	15	3	70
Frequency Missing = 13				

5.4.2 Pakistani Experience and Different Reduction Levels on Highways

Analysis has shown that Pakistani experience is not a significant factor affecting comfort level for any reduction level in taper length on highways. Table 5.21 gives probability values.

Table 5.21 Probability Values for Pakistani Experience vs Reduction for Highways

Reductions	Fisher's Test P-Value	Chi Square Test		
		D.F	Chi Sq Value	P-Value
No Reduction	0.7623	6	2.3384	0.8861
10%	0.8418	6	2.3348	0.8865
20%	0.139	6	8.7259	0.1896
30%	0.5605	6	4.9075	0.5557
40%	0.2209	6	7.8342	0.2505

5.4.2.1 No Reduction on Highways

Pakistani experience is not a significant factor at "no reduction" in taper length. (P-Value=0.7623). Table 5.22 shows no significant over/under representation for Pakistani experience versus comfort level.

Table 5.22 Chi Square for Pakistani Experience No Reduction level on Highway

Table of Pak_Exp by HR00				
Pak-Exp	**Comfort Level**			
Frequency **Expected** **Cell Chi-Square**	**1**	**2**	**3**	**Total**
1	0 0.1159 0.1159	0 0.1304 0.1304	1 0.7536 0.0805	1
2	1 0.4638 0.62	0 0.5217 0.5217	3 3.0145 0.0001	4
3	2 1.5072 0.1611	1 1.6957 0.2854	10 9.7971 0.0042	13
4	5 5.913 0.141	8 6.6522 0.2731	38 38.435 0.0049	51
Total	8	9	52	69
Frequency Missing = 14				

5.4.2.2 10% Reduction on Highways

Pakistani experience is not a significant factor at 10% reduction in taper length. (P-Value=0.8418). Table 5.23 shows no significant over/under representation.

Table 5.23 Chi Square for Pakistani Experience 10% Reduction level on Highway

Table of Pak_Exp by HR10				
Pak_Exp	**HR10**			
Frequency **Expected** **Cell Chi-Square**	**1**	**2**	**3**	**Total**
1	0 0.1571 0.1571	0 0.2571 0.2571	1 0.5857 0.293	1
2	1 0.7857 0.0584	2 1.2857 0.3968	2 2.9286 0.2944	5
3	2 2.0429 0.0009	2 3.3429 0.5394	9 7.6143 0.2522	13
4	8 8.0143 255E-7	14 13.114 0.0598	29 29.871 0.0254	51
Total	11	18	41	70
Frequency Missing = 13				

5.4.2.3 20% Reduction on Highways

Pakistani experience is not a significant factor at 20% reduction in taper length. (P-Value=0.139). Actual frequencies are close to expected frequencies and no significant over or under-representation is observed in Table 5.24.

Table 5.24 Chi Square for Pakistani Experience and 20% Reduction level on Highway

Table of Pak-Exp by HR20				
Pak-Exp	**Comfort Levels**			
Frequency **Expected** **Cell Chi-Square**	**1**	**2**	**3**	**Total**
1	0 0.3714 0.3714	0 0.3286 0.3286	1 0.3 1.6333	1
2	3 1.8571 0.7033	2 1.6429 0.0776	0 1.5 1.5	5
3	2 4.8286 1.657	7 4.2714 1.743	4 3.9 0.0026	13
4	21 18.943 0.2234	14 16.757 0.4536	16 15.3 0.032	51
Total	26	23	21	70
Frequency Missing = 13				

5.4.2.4 30% Reduction on Highways

Pakistani experience is not a significant factor at 30% reduction in taper length. (P-Value=0.5605). No significant over or under representation is observed in Table 5.25.

Table 5.25 Chi Square for Pakistani Experience and 30% Reduction level on Highway

Table of Pak_Exp by HR30				
Pak_Exp	**HR30**			
Frequency **Expected** **Cell Chi-Square**	**1**	**2**	**3**	**Total**
1	0 0.6714 0.6714	1 0.2429 2.3605	0 0.0857 0.0857	1
2	4 3.3571 0.1231	1 1.2143 0.0378	0 0.4286 0.4286	5
3	9 8.7286 0.0084	2 3.1571 0.4241	2 1.1143 0.704	13
4	34 34.243 0.0017	13 12.386 0.0305	4 4.3714 0.0316	51
Total	47	17	6	70
Frequency Missing = 13				

5.4.2.5 40% Reduction on Highways

Pakistani experience is not a significant factor at “no reduction” in taper length. (P-Value=0.2209). No significant over or under representation is observed in Table 5.26.

Table 5.26 Chi Square for Pakistani Experience and 40% Reduction level on Highway

Table of Pak_Exp by HR40				
Pak_Exp	**HR40**			
Frequency Expected Cell Chi-Square	**1**	**2**	**3**	**Total**
1	0 0.8286 0.8286	1 0.1429 5.1429	0 0.0286 0.0286	1
2	4 4.1429 0.0049	1 0.7143 0.1143	0 0.1429 0.1429	5
3	10 10.771 0.0552	2 1.8571 0.011	1 0.3714 1.0637	13
4	44 42.257 0.0719	6 7.2857 0.2269	1 1.4571 0.1434	51
Total	58	10	2	70
Frequency Missing = 13				

5.4.3 Discussion

For motorways, driving experience in Pakistanis a significant factor for 30 and 40% reduction. It is observed that participants with Pakistani experience upto 10 years are under-represented and participants with driving experience more than 10 years are over represented in comfortable zone.

For, highways driving experience in Pakistan is not a significant factor. This behavior was also observed with age factor.

5.5 Home Province Vs Taper Length Reduction

The question asked in the survey was

"In which province of Pakistan do you reside?"

The results showed that province is a significant for both motorways and highways. Only two responses came from Gilgit Baltistan therefore it was combined with Khyber Pukhtunkhwa.

5.5.1 Province and Different Reduction Levels on Motorways

Upon analysis it was observed that province is a significant factor for 10 and 20% reduction levels with Fisher exact test probability value of 0.0025 and 0.0957. Table 5.27 gives P-values for different levels of reduction.

Table 5.27 Probability Values for Province vs Reduction for Motorways

Reductions	Fisher's Test P-Value	Chi Square Test		
		D.F	Chi Sq Value	P-Value
No Reduction	0.2077	8	12.657	0.1242
10%	0.0025	8	22.6261	0.0039
20%	0.0957	8	13.6849	0.0904
30%	0.2425	8	10.6578	0.2219
40%	0.3462	8	8.2688	0.4077

5.5.1.1 No Reduction on Motorways

Province is not a significant factor at “no reduction”. (P-Value= 0.2077). Table 5.28 provides chi square values for Province versus comfort level.

Table 5.28 Chi Square for Province and No Reduction level on Motorway

Table of Province by MR00				
Province	**Comfort Levels**			
Frequency **Expected** **Cell Chi-Square**	**1**	**2**	**3**	**Total**
Balochistan	0 0.506 0.506	4 1.1807 6.7317	3 5.3133 1.0071	7
Islamabad (Capital)	1 0.4337 0.7393	0 1.012 1.012	5 4.5542 0.0436	6
KPK+GB	0 0.4337 0.4337	0 1.012 1.012	6 4.5542 0.459	6
Punjab	4 3.1084 0.2557	6 7.253 0.2165	33 32.639 0.004	43
Sindh	1 1.5181 0.1768	4 3.5422 0.0592	16 15.94 0.0002	21
Total	6	14	63	83

*Khyber Pukhtunkhwa KPK
Gilgit Baltistan GB

5.5.1.2 10% Reduction on Motorways

With P-value of 0.0025, relationship between province and comfort level is strong. Chi square values suggest that participants from Balochistan and Sindh are over represented in uncomfortable zone and underrepresented in comfortable zone. Participants form Punjab are underrepresented in uncomfortable zone and over represented in comfortable zone. (Table 5.29)

Table 5.29 Chi Square for Province and 10% Reduction level on Motorway

Table of Province by MR10				
Province	**Comfort Levels**			
Frequency **Expected** **Cell Chi-Square**	**1**	**2**	**3**	**Total**
Balochistan	3 1.012 3.9049	2 1.2651 0.427	2 4.7229 1.5698	7
Islamabad (Capital)	1 0.8675 0.0202	0 1.0843 1.0843	5 4.0482 0.2238	6
KPK+GB	0 0.8675 0.8675	0 1.0843 1.0843	6 4.0482 0.941	6
Punjab	3 6.2169 1.6645	5 7.7711 0.9881	35 29.012 1.2359	43
Sindh	5 3.0361 1.2703	8 3.7952 4.6587	8 14.169 2.6857	21
Total	12	15	56	83

5.5.1.3 20% Reduction on Motorways

Province is a significant factor for 20% reduction with P-value 0.0957. Participants from Sindh are under-represented in comfortable zone, participants from Balochistan are over represented in uncomfortable zone and participants from Khyber Pukhtunkhwa are over represented and from Balochistan are underrepresented in comfort level 2 as shown in Table 5.30.

Table 5.30 Chi Square for Province and 20% Reduction level on Motorway

Table of Province by MR20				
Province	**Comfort Levels**			
Frequency **Expected** **Cell Chi-Square**	**1**	**2**	**3**	**Total**
Balochistan	5 2.1928 3.5939	0 1.8554 1.8554	2 2.9518 0.3069	7
Islamabad (Capital)	1 1.8795 0.4116	1 1.5904 0.2191	4 2.5301 0.8539	6
KPK+GB	1 1.8795 0.4116	3 1.5904 1.2495	2 2.5301 0.1111	6
Punjab	10 13.47 0.8939	11 11.398 0.0139	22 18.133 0.8249	43
Sindh	9 6.5783 0.8915	7 5.5663 0.3693	5 8.8554 1.6786	21
Total	26	22	35	83

5.5.1.4 30% Reduction on Motorways

Province is not a significant factor on motorways for 30% reduction in taper length with P-value 0.2425. No significant over or under representation is observed in Table 5.31.

Table 5.31 Chi Square for Province and 30% Reduction level on Motorway

Table of Province by MR30				
Province	**MR30**			
Frequency Expected Cell Chi-Square	**1**	**2**	**3**	**Total**
Balochistan	5 4.0122 0.2432	0 1.622 1.622	2 1.3659 0.2944	7
Islamabad (Capital)	2 3.439 0.6021	1 1.3902 0.1095	3 1.1707 2.8582	6
KPK+GB	3 3.439 0.056	3 1.3902 1.8639	0 1.1707 1.1707	6
Punjab	23 24.646 0.11	11 9.9634 0.1078	9 8.3902 0.0443	43
Sindh	14 11.463 0.5613	4 4.6341 0.0868	2 3.9024 0.9274	20
Total	47	19	16	82
Frequency Missing = 1				

5.5.1.5 40% Reduction on Motorways

Province is not a significant factor on motorways for 40% reduction in taper length with P-value 0.3462. As shown in table 5.32 no group is significantly over/ under represented for Province versus Comfort level.

Table 5.32 Chi Square for Province and 40% Reduction level on Motorway

Table of Province by MR40				
Province	**MR40**			
Frequency **Expected** **Cell Chi-Square**	**1**	**2**	**3**	**Total**
Balochistan	5 5.1446 0.0041	2 1.3494 0.3137	0 0.506 0.506	7
Islamabad (Capital)	2 4.4096 1.3167	3 1.1566 2.9379	1 0.4337 0.7393	6
KPK+GB	5 4.4096 0.079	1 1.1566 0.0212	0 0.4337 0.4337	6
Punjab	31 31.602 0.0115	8 8.2892 0.0101	4 3.1084 0.2557	43
Sindh	18 15.434 0.4267	2 4.0482 1.0363	1 1.5181 0.1768	21
Total	61	16	6	83

5.5.2 Province and Different Reduction Levels on Highways

For Highways, relationship is found to be significant between province and comfort level for 20 and 40% reduction levels. Table 5.33 gives the probability values.

Table 5.33 Probability Values for Provinces Vs Reduction for Highways

Reductions	Fisher's Test P-Value	Chi Square Test		
		D.F	Chi Sq Value	P-Value
No Reduction	0.2194	8	10.6429	0.2228
10%	0.2539	8	8.7893	0.3604
20%	0.0277	8	15.4058	0.0517
30%	0.1085	8	11.193	0.191
40%	0.088	8	12.4351	0.1328

5.5.2.1 No Reduction on Highways

Province is not a significant factor for highways at no reduction in taper length. (P-Value=0.2194). No significant over or underrepresentation is observed in Table 5.34.

Table 5.34 Chi Square for Province No Reduction level on Highway

Table of Province by HR00				
Province	**Comfort Levels**			
Frequency **Expected** **Cell Chi-Square**	**1**	**2**	**3**	**Total**
Balochistan	1 0.939 0.004	3 0.8537 5.3965	3 5.2073 0.9357	7
Islamabad (Capital)	1 0.8049 0.0473	0 0.7317 0.7317	5 4.4634 0.0645	6
KPK+GB	1 0.8049 0.0473	0 0.7317 0.7317	5 4.4634 0.0645	6
Punjab	5 5.7683 0.1023	3 5.2439 0.9602	35 31.988 0.2836	43
Sindh	3 2.6829 0.0375	4 2.439 0.999	13 14.878 0.2371	20
Total	11	10	61	82
Frequency Missing = 1				

5.5.2.2 10% Reduction on Highways

Province is not a significant factor for highways at 10% reduction factor. (P-Value=0.2593). No province is significantly under or over represented in Province Vs comfort level. (Table 5.35)

Table 5.35 Chi Square for Province for 10% Reduction level on Highway

Table of Province by HR10				
Province	**Comfort Level**			
Frequency **Expected** **Cell Chi-Square**	**1**	**2**	**3**	**Total**
Balochistan	2 1.0964 0.7447	3 1.7711 0.8527	2 4.1325 1.1005	7
Islamabad (Capital)	1 0.9398 0.0039	0 1.5181 1.5181	5 3.5422 0.6	6
KPK+GB	1 0.9398 0.0039	1 1.5181 0.1768	4 3.5422 0.0592	6
Punjab	5 6.7349 0.4469	9 10.88 0.3247	29 25.386 0.5146	43
Sindh	4 3.2892 0.1536	8 5.3133 1.3586	9 12.398 0.9311	21
Total	13	21	49	83

5.5.2.3 20% Reduction on Highways

Province is a significant factor for highways at 20% reduction level. (P-Value=0.0277). Data is over represented for participants from Balochistan in uncomfortable zone. Data is over-represented for participants from Punjab and under-represented for participants from Sindh in comfortable zone. (Table 5.36).

Table 5.36 Chi Square values for Province and 20% Reduction level on Highway

Table of Province by HR20				
Province	**HR20**			
Frequency **Expected** **Cell Chi-Square**	**1**	**2**	**3**	**Total**
Balochistan	5 2.5301 2.4111	1 2.2771 0.7163	1 2.1928 0.6488	7
Islamabad (Capital)	1 2.1687 0.6298	3 1.9518 0.5629	2 1.8795 0.0077	6
KPK+GB	3 2.1687 0.3187	0 1.9518 1.9518	3 1.8795 0.668	6
Punjab	11 15.542 1.3274	14 13.988 104E-7	18 13.47 1.5235	43
Sindh	10 7.5904 0.765	9 6.8313 0.6885	2 6.5783 3.1864	21
Total	30	27	26	83

5.5.2.4 30% Reduction on Highways

Province is not a significant factor at 30% reduction level (P-Value=0.1085). There is no significant over and under representation in the data. (Table 5.37)

Table 5.37 Chi Square values for Province and 30% Reduction level on Highway

Table of Province by HR30				
Province	**Comfort Levels**			
Frequency **Expected** **Cell Chi-Square**	**1**	**2**	**3**	**Total**
Balochistan	5 4.6386 0.0282	2 1.5181 0.153	0 0.8434 0.8434	7
Islamabad (Capital)	3 3.9759 0.2395	1 1.3012 0.0697	2 0.7229 2.2562	6
KPK+GB	3 3.9759 0.2395	2 1.3012 0.3753	1 0.7229 0.1062	6
Punjab	25 28.494 0.4284	12 9.3253 0.7672	6 5.1807 0.1296	43
Sindh	19 13.916 1.8577	1 4.5542 2.7738	1 2.5301 0.9254	21
Total	55	18	10	83

5.5.2.5 40% Reduction on Highways

Province is a significant factor at 40% reduction level with Fisher Exact test P-value of 0.088. The actual and expected frequencies are close except for over representation of participants from Khyber Pukhtunkhwa in comfort level2. (Table 5.38)

Table 5.38 Chi Square values for Province and 40% Reduction level on Highway

Table of Province by HR40				
Province	**HR40**			
Frequency Expected Cell Chi-Square	**1**	**2**	**3**	**Total**
Balochistan	6 5.6506 0.0216	1 0.9277 0.0056	0 0.4217 0.4217	7
Islamabad (Capital)	4 4.8434 0.1469	1 0.7952 0.0528	1 0.3614 1.1281	6
KPK+GB	3 4.8434 0.7016	3 0.7952 6.1134	0 0.3614 0.3614	6
Punjab	34 34.711 0.0146	6 5.6988 0.0159	3 2.5904 0.0648	43
Sindh	20 16.952 0.5481	0 2.7831 2.7831	1 1.2651 0.0555	21
Total	67	11	5	83

5.5.3 Discussion

Province of residence in Pakistan is a significant factor for motorways (for 10 and 20% reduction) and highways (20 and 40%). In general, participants from Punjab are under-represented and participants from Sindh and Balochistan are over represented in uncomfortable zone.

Figure 5.3 Pakistani Motorways (Only M1, M2, and M3 have been constructed)

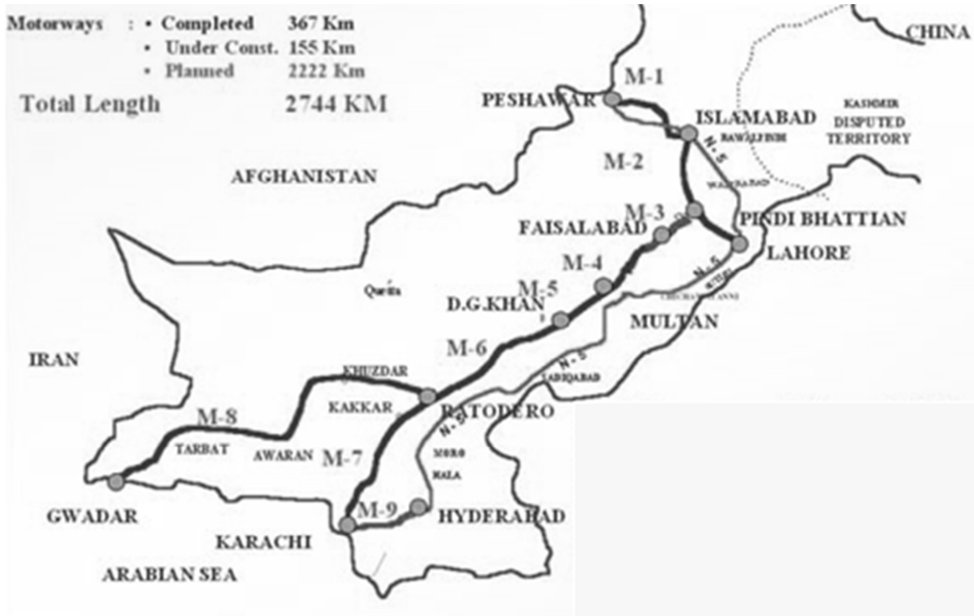
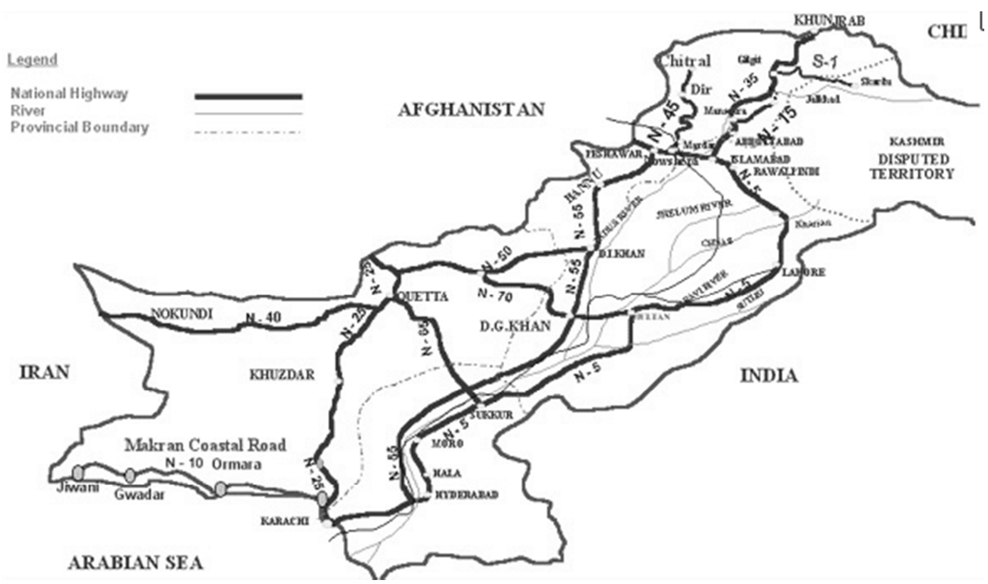


Figure 5.4 Pakistani Highways



Currently, all the constructed and operational motorways are either in Punjab or KPK. (Khyber Pukhtunkhwa) and there are no operational motorways in Sindh and Balochistan.

Fig 5.3 and 5.4 show the motorways and highways in Pakistan. This may explain over representation of data for participants from Balochistan and Sindh in uncomfortable zone. However, same trend for highways cannot be explained.

5.6 U.S Driving Experience Vs Taper Length Reduction

U.S driving experience is not a significant factor in both motorways and highways. Since the range of experience for responses was large (o to 40 years), it was divided into categories as for Pakistani driving experience and analyzed. The results showed that the factor is not significant for both motorways and highways for any level of reduction. Chi square table are placed at Appendix-II.

Table 5.39 Probability Values for Provinces Vs Reduction

Reductions	Motorways				Highways			
	Fisher's Test P-Value	Chi Square Test			Fisher's Test P-Value	Chi Square Test		
		D.F	Chi Sq Value	P-Value		D.F	Chi Sq Value	P-Value
No Reduction	0.3682	6	8.514	0.2028	0.6463	6	3.9897	0.6781
10%	0.2303	6	7.8335	0.2506	0.8009	6	3.6759	0.7204
20%	0.2329	6	9.5313	0.1458	0.6617	6	3.8858	0.6921
30%	0.7106	6	3.6584	0.7228	0.9577	6	1.9275	0.9262
40%	0.6332	6	3.8854	0.6922	0.8662	6	1.8264	0.9349

5.7 Gender Vs Taper Length Reduction

This analysis could not be performed since there were only 3 females in the original data and none in the filtered data.

5.8 U.S Residence State Vs Taper Length Reduction

People from 26 states participated in the survey. The states were grouped as provided in Table 5.40. U.S residence state is found to be insignificant for both motorways and highways. Probability are given in Table 5.42. Chi square table are placed at Appendix-III.

Table 5.40 Regions in US

Regions	Frequency of Responses
Midwest	32
North East	5
West	6
South	38
Frequency Missing = 2	

Table 5.41 Probability Values for Provinces Vs Reduction

Reductions	Motorways				Highways			
	Fisher's Test P-Value	Chi Square Test			Fisher's Test P-Value	Chi Square Test		
		D.F	Chi Sq Value	P-Value		D.F	Chi Sq Value	P-Value
No Reduction	0.1399	6	9.5203	0.1464	0.2828	6	4.7439	0.5771
10%	0.0389	6	14.0192	0.0294	0.3694	6	5.4176	0.4915
20%	0.3714	6	7.6831	0.2623	0.5096	6	6.1227	0.4096
30%	0.7642	6	3.7365	0.7123	0.9696	6	1.8652	0.9317
40%	1	6	1.2188	0.9759	0.9909	6	3.0561	0.8018

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

It is concluded in study that average comfort level for respondents on motorways is greater than that on highways for reduction up to 30%. Majority of respondents fall either in “comfortable” or “neither comfortable nor uncomfortable” for reduction up to 20%. Further decrease in reduction causes majority to shift to “uncomfortable” zone. A 40% reduction makes a great majority of the participant uncomfortable. So it is not appropriate level of reduction. Based on this, a reduction level of somewhere between 20 and 30% may be suitable. A 20% reduction in taper length brings the average comfort level to 3.108 for motorways and 2.891 for highways, whereas a value of 3 is for “neither comfortable nor uncomfortable”. A 30% reduction in taper length brings the average comfort level to 2.439 for motorways and 2.241 for highways. Keeping the above factors in view it is concluded that a reduction between 20 and 30% would be appropriate and therefore a reduction of 25% is recommended for motorways. Although the comfort level is low on highways as compared to motorways but the speed limit is also lesser on highways than on motorways. The same conclusions can be applied to highways as well.

Following are other conclusions drawn in the study:

1- For motorways, Age is a significant factor in driver’s response to comfort level for 20 and 30% reduction in taper length whereas for highways, age is a significant factor in driver’s response to comfort level for 10% reduction in taper length.
2- Driving experience in Pakistan is a significant factor in driver’s response to comfort level for motorways but not for highways. For motorways, participants with driving

experience more than 10 years are over represented in uncomfortable zone for 30 and 40% level of reduction.

3- Province of residence of respondent in Pakistan is a significant factor in driver's response to comfort level for both motorways (at 10 and 20% reduction) and highways (20 and 40% reduction). For both motorways and highways, Punjab is under represented in uncomfortable zone for level of reductions which have significant dependence.

4- US residence state and driving experience is not a significant factor.

The conclusions from the study are limited by the following factors.

- Total number of responses is small. A total of 108 responses were received and 83 of these are used for analysis.
- Only 3 females participated in the survey and none of these surveys are included in final analysis due to filtration of data.
- Majority of the responses came from age group 26 to 45 years.

It is recommended, that further research be conducted to larger samples from all age groups, more female drivers, and a large number of participant.

It is also recommended that the conclusions drawn in this study be verified with the field data when a 25% reduction in taper length in Pakistani work zones is implemented at those sites where the safety and comfort level of motorist is not compromised.

It is further recommended that all aspects of work zone traffic management be studied based on methodology in this thesis to be validated by field studies later on to develop a thorough set of documents for future needs.

REFERENCES

Beacher, A. G., Fontaine, M. D., & Garber, N. J. (2005). Field evaluation of late merge traffic control in work zones, *Transportation Research Record, Issue Number: 1911, pp 33-41.*

Benekohal R.F, H. Ramezani, and K.A. Avrenli. (2010). Queue and User's costs in highway work zones. *FHWA-ICT-10-075.*

Bhatti, J. A., Razzak, J. A., Lagarde, E., & Salmi, L. R. (2011). Burden and factors associated with highway work-zone crashes, on a section of the karachi-Hala road, Pakistan. *Injury Prevention, 17(2), 79-83.*

Datta, T. K. (2001). Development and evaluation of the lane merge traffic control system at construction work zones. *Michigan Department of Transportation, Research report No. RC-1411.*

General specifications, National Highway Authority Pakistan, (1998).

Graham, J. L., Harwood, D. W., & Sharp, M. C. (1979). Effects of taper length on traffic operations in construction zones. *Transportation Research Record, Issue No: 70, pp 19-24.*

Hoyer, W. J., & Familant, M. E. (1987). Adult age differences in the rate of processing expectancy information. *Cognitive Development, vol 2(1), pp 59-70.*

Heaslip, K., Collura, J., & Knodler, M. (2011). Evaluation of work zone design features to aid older drivers. *ITE Journal (Institute of Transportation Engineers), 81(3), pp 36-40.*

John Collura, Chuck Louisell, Kevin Heaslip. (2008). Driver population adjustment factors for the highway capacity manual work zone capacity equation. *Transportation Research Board.*

Manual on uniform traffic control devices (2009) – *FHWA.*

Mihal, W. L., & Barrett, G. V. (1976). Individual differences in perceptual information processing and their relation to automobile accident involvement. *Journal of Applied Psychology, 61(2), pp 229-233.*

Pakistan Transport Plan Study. (2006). *Japan International Cooperation Agency (JICA) & National Transport Research Centre. (NTRC).*

Patrick,T.M., & Geza,P. (2001). Dynamic late merge control concept for work zones on rural interstate highways. *Transportation Research Board. Issue No: 1745, pp 20-26.*

Pesti, G., Jessen, D. R., Byrd, P. S., & McCoy, P. T. (1999). Traffic flow characteristics of the late merge work zone strategy. *Transportation Research Record, Issue No: 1657 pp 3341.*

Razzak JA, Luby SP (1998). Estimating deaths and injuries due to road traffic accidents in Karachi, Pakistan, through the capture-recapture method. *International Journal of Epidemiolog. Volume: 27 Issue No: 5 pp 866-870.*

Road Safety in Pakistan. (2007). *National Road Safety secretariat, Ministry of Communications, Government of Pakistan.*

Tapan, K. D., Kerrie, L. S., & Colleen, H. (2002). Driver behavior and safety at construction zone lane merge situations. *Association of European Transport.*

Tarko, A. P., Shamo, D., & Wasson, J. (1999). Indiana lane merge system for work zones on rural freeways. *Journal of Transportation Engineering, 125(5), pp 415-420.*

World Health Organization. *http://apps.who.int/ghodata/?vid=51210#*

APPENDIX-A

QUESTIONNAIRE

PART-I

This part consists of general demographic questions.

1- Gender
- o Male
- o Female

2- What is your age group
- o 20 or under 20 years
- o 21-25 years
- o 26-35 years
- o 36-45 years
- o 46-55 years
- o 56-65 years
- o Greater than 65 years

3- Do you have a US driver's license?
- o Yes
- o No

If yes, how long have you had a US driver's license? -----

4- Do you have a Pakistani driver's license?
- o Yes
- o No

If yes, how long have you had a US driver's license? -----

5- Have you driven through a work zone in US
- o Yes
- o No

6- Have you driven through a work zone in Pakistan?
- o Yes
- o No

7- Have you had any accident in work zone in US?
- o Yes
- o No

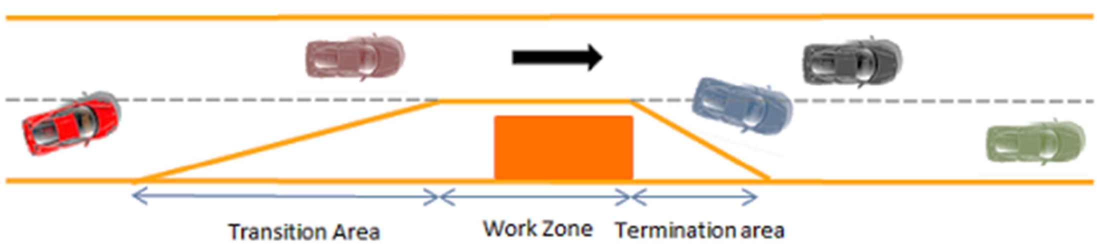
8- Have you had any accident in work zone in Pakistan?
- o Yes
- o No

9- In which state of US do you reside? --------------

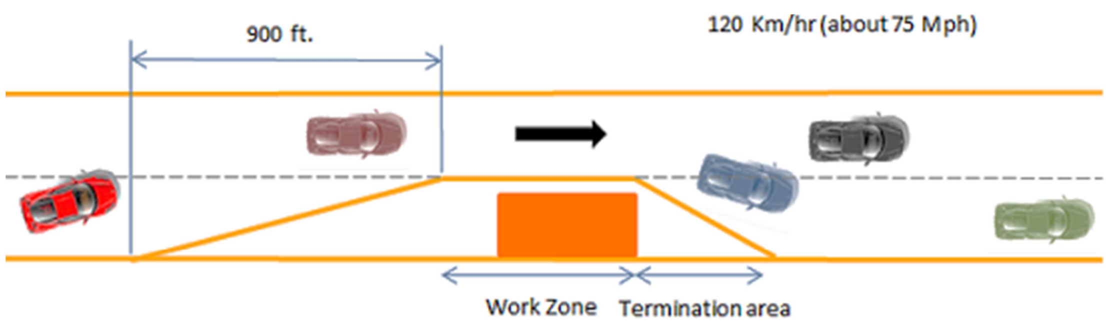
10- In which province of Pakistan do you reside? --------------

PART-II

Following is the schematic of a typical US freeway work zone. In the next 5 questions you will be asked to indicate your comfort level as the length of transition is reduced from 900 ft to 540 ft.

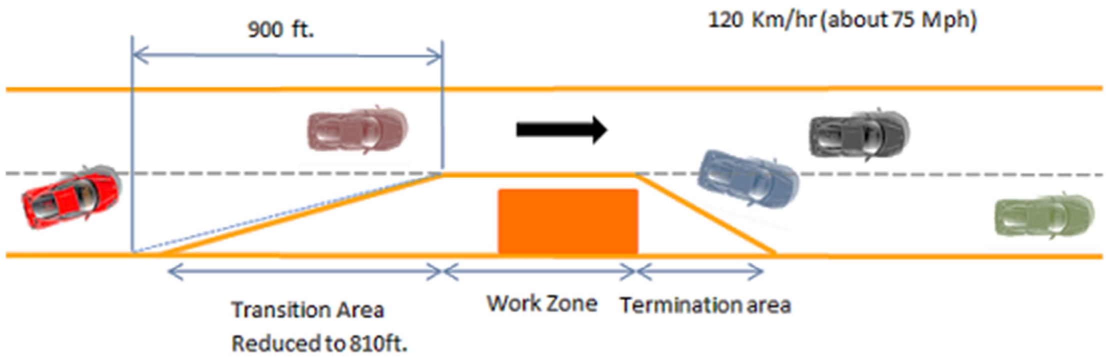


11- In the U.S, for a freeway approach speed of 120 km/hr (about 75 Mph), standard taper length is 900 ft. indicate your comfort level while going through a work zone with standard taper length? (No reduction in taper length).



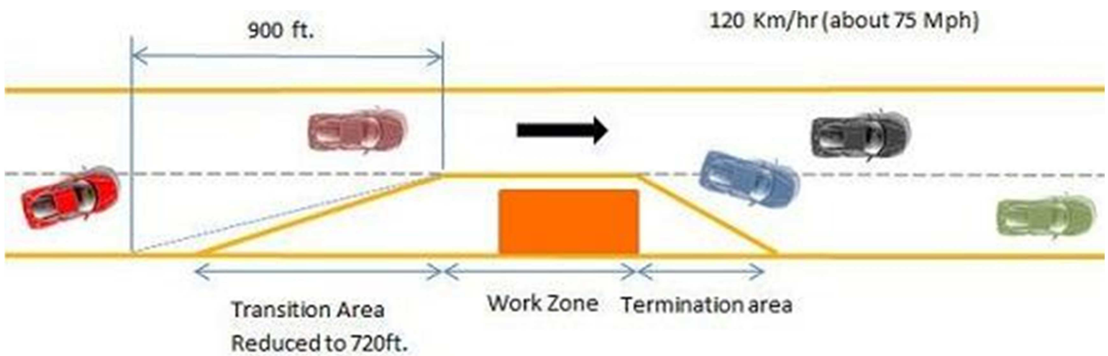
- o Very comfortable
- o Somewhat Comfortable
- o Neither comfortable nor uncomfortable
- o Somewhat Uncomfortable
- o Very uncomfortable

12- Imagine you are driving on a Pakistani Motorway at speed of 120km/hr (about 75 Mph), indicate your comfort level if the taper length is reduced to 810 ft.



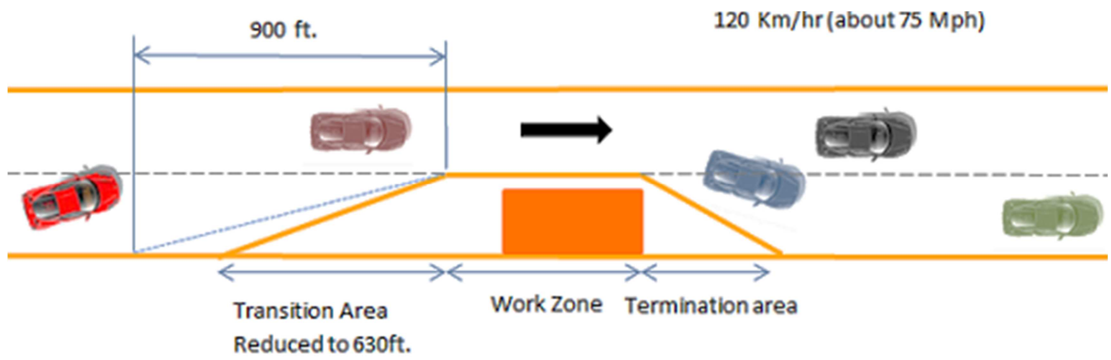
- o Very comfortable
- o Somewhat Comfortable
- o Neither comfortable nor uncomfortable
- o Somewhat Uncomfortable
- o Very uncomfortable

13- Imagine you are driving on a Pakistani Motorway at speed of 120km/hr (about 75 Mph), indicate your comfort level if the taper length is reduced to 720 ft.



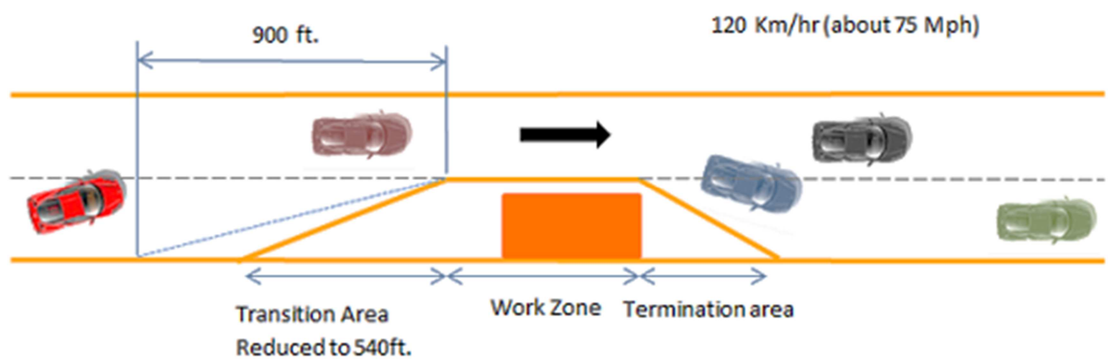
- o Very comfortable
- o Somewhat Comfortable
- o Neither comfortable nor uncomfortable
- o Somewhat Uncomfortable
- o Very uncomfortable

14- Imagine you are driving on a Pakistani Motorway at speed of 120km/hr (about 75 Mph), indicate your comfort level if the taper length is reduced to 630 ft.



- o Very comfortable
- o Somewhat Comfortable
- o Neither comfortable nor uncomfortable
- o Somewhat Uncomfortable
- o Very uncomfortable

15- Imagine you are driving on a Pakistani Motorway at speed of 120km/hr (about 75 Mph), indicate your comfort level if the taper length is reduced to 540 ft.

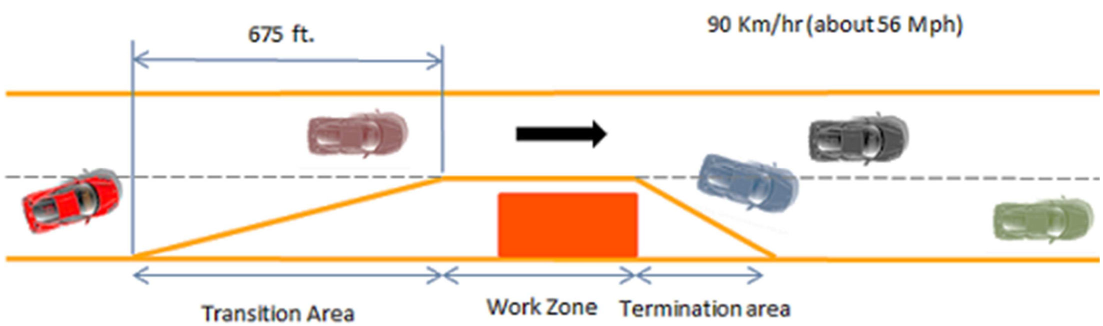


- o Very comfortable
- o Somewhat Comfortable
- o Neither comfortable nor uncomfortable
- o Somewhat Uncomfortable
- o Very uncomfortable

PART-III

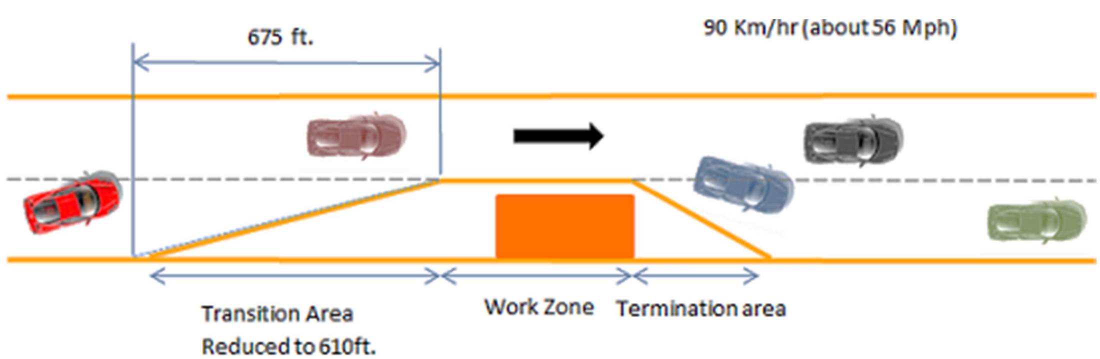
This part consists of similar questions as given in Part-II. However, this part is for highways (not freeways). Indicate your comfort level as the length of transition is reduced from 675 ft to 410 ft.

16- In the U.S, for a highway approach speed of 90 km/hr (about 56 Mph), standard taper length is 675 ft. Indicate your comfort level while crossing a work zone with standard taper length?



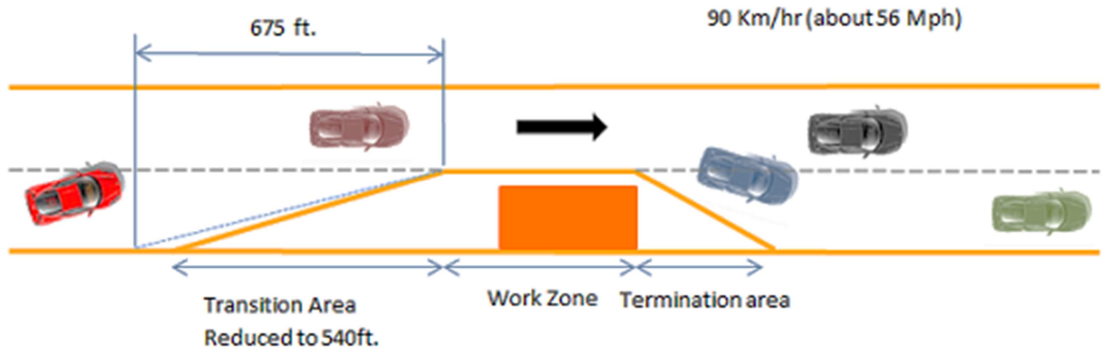
- o Very comfortable
- o Somewhat Comfortable
- o Neither comfortable nor uncomfortable
- o Somewhat Uncomfortable
- o Very uncomfortable

17- Imagine you are driving on a Pakistani National highway at speed of 90 km/hr (about 56 Mph) indicate your comfort level if the taper length is reduced to 610 ft.



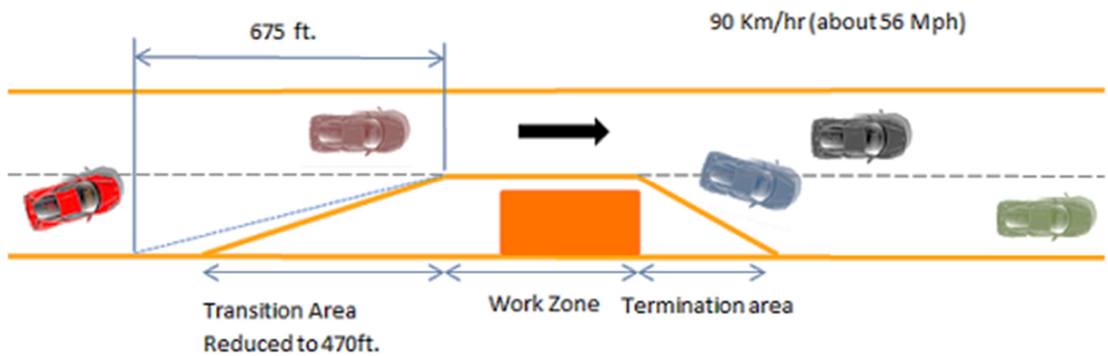
- o Very comfortable
- o Somewhat Comfortable
- o Neither comfortable nor uncomfortable
- o Somewhat Uncomfortable
- o Very uncomfortable

18- Imagine you are driving on a Pakistani National highway at speed of 90 km/hr (about 56 Mph)describe your comfort level if the taper length is reduced to 540 ft.



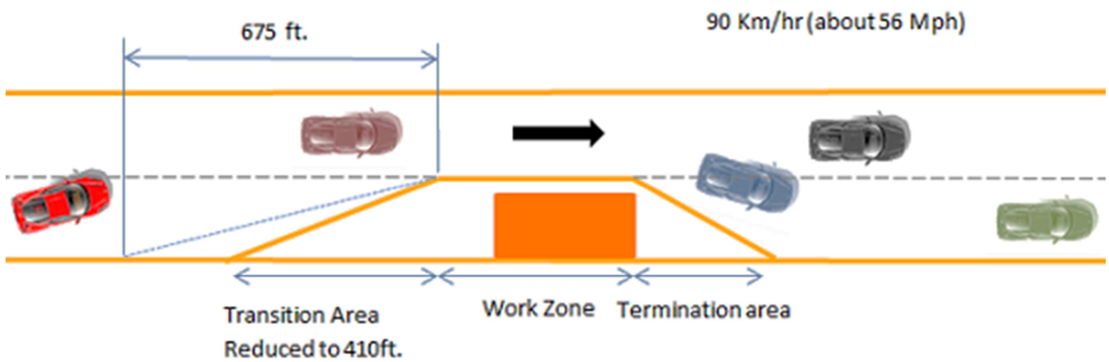
- o Very comfortable
- o Somewhat Comfortable
- o Neither comfortable nor uncomfortable
- o Somewhat Uncomfortable
- o Very uncomfortable

19- Imagine you are driving on a Pakistani National highway at speed of 90km/hr (about 56 Mph), indicate your comfort level if the taper length is reduced to 470 ft.



- o Very comfortable
- o Somewhat Comfortable
- o Neither comfortable nor uncomfortable
- o Somewhat Uncomfortable
- o Very uncomfortable

20- Imagine you are driving on a Pakistani National highway at speed of 90 km/hr (about 56 Mph) indicate your comfort level if the taper length is reduced to 410 ft.



- o Very comfortable
- o Somewhat Comfortable
- o Neither comfortable nor uncomfortable
- o Somewhat Uncomfortable
- o Very uncomfortable

APPENDIX-B

Tables for Chi Square Values for Motorways and Highways
U.S Experience Vs Comfort Level

Table of US_Exp by MR00				
US_Exp	**Comfort Level**			
Frequency **Expected** **Cell Chi-Square**	**1**	**2**	**3**	**Total**
1	0 0.7952 0.7952	1 1.8554 0.3944	10 8.3494 0.3263	11
2	2 2.8193 0.2381	7 6.5783 0.027	30 29.602 0.0053	39
3	3 0.8675 5.2425	1 2.0241 0.5181	8 9.1084 0.1349	12
4	1 1.5181 0.1768	5 3.5422 0.6	15 15.94 0.0554	21
Total	6	14	63	83

Table of US_Exp by MR10				
US_Exp	**Comfort Level**			
Frequency **Expected** **Cell Chi-Square**	**1**	**2**	**3**	**Total**
1	2 1.5904 0.1055	1 1.988 0.491	8 7.4217 0.0451	11
2	4 5.6386 0.4762	7 7.0482 0.0003	28 26.313 0.1081	39
3	3 1.7349 0.9224	0 2.1687 2.1687	9 8.0964 0.1008	12
4	3 3.0361 0.0004	7 3.7952 2.7063	11 14.169 0.7086	21
Total	12	15	56	83

Table of US_Exp by MR20				
US_Exp	**Comfort Level**			
Frequency Expected Cell Chi-Square	**1**	**2**	**3**	**Total**
1	2 3.4458 0.6066	7 2.9157 5.7214	2 4.6386 1.5009	11
2	12 12.217 0.0038	9 10.337 0.173	18 16.446 0.1469	39
3	4 3.759 0.0154	2 3.1807 0.4383	6 5.0602 0.1745	12
4	8 6.5783 0.3073	4 5.5663 0.4407	9 8.8554 0.0024	21
Total	26	22	35	83

Table of US_Exp by MR30				
US_Exp	**Comfort Level**			
Frequency Expected Cell Chi-Square	**1**	**2**	**3**	**Total**
1	6 6.3049 0.0147	4 2.5488 0.8263	1 2.1463 0.6123	11
2	24 21.78 0.2262	7 8.8049 0.37	7 7.4146 0.0232	38
3	5 6.878 0.5128	4 2.7805 0.5349	3 2.3415 0.1852	12
4	12 12.037 0.0001	4 4.8659 0.1541	5 4.0976 0.1988	21
Total	47	19	16	82
Frequency Missing = 1				

Table of US_Exp by MR40				
US_Exp	**Comfort Level**			
Frequency Expected Cell Chi-Square	**1**	**2**	**3**	**Total**
1	8 8.0843 0.0009	2 2.1205 0.0068	1 0.7952 0.0528	11
2	31 28.663 0.1906	5 7.5181 0.8434	3 2.8193 0.0116	39
3	9 8.8193 0.0037	2 2.3133 0.0424	1 0.8675 0.0202	12
4	13 15.434 0.3838	7 4.0482 2.1524	1 1.5181 0.1768	21
Total	61	16	6	83

Table of US_Exp by HR00				
US_Exp	**Comfort Level**			
Frequency Expected Cell Chi-Square	**1**	**2**	**3**	**Total**
1	1 1.4756 0.1533	2 1.3415 0.3233	8 8.1829 0.0041	11
2	4 5.0976 0.2363	3 4.6341 0.5763	31 28.268 0.264	38
3	3 1.6098 1.2007	1 1.4634 0.1467	8 8.9268 0.0962	12
4	3 2.8171 0.0119	4 2.561 0.8086	14 15.622 0.1684	21
Total	11	10	61	82
Frequency Missing = 1				

Table of US_Exp by HR10				
US_Exp	**Comfort Level**			
Frequency Expected Cell Chi-Square	**1**	**2**	**3**	**Total**
1	1 1.7229 0.3033	3 2.7831 0.0169	7 6.494 0.0394	11
2	5 6.1084 0.2011	11 9.8675 0.13	23 23.024 252E-7	39
3	4 1.8795 2.3923	2 3.0361 0.3536	6 7.0843 0.166	12
4	3 3.2892 0.0254	5 5.3133 0.0185	13 12.398 0.0293	21
Total	13	21	49	83

Table of US_Exp by HR20				
US_Exp	**Comfort Level**			
Frequency Expected Cell Chi-Square	**1**	**2**	**3**	**Total**
1	4 3.9759 0.0001	3 3.5783 0.0935	4 3.4458 0.0891	11
2	14 14.096 0.0007	12 12.687 0.0372	13 12.217 0.0502	39
3	6 4.3373 0.6373	5 3.9036 0.3079	1 3.759 2.0251	12
4	6 7.5904 0.3332	7 6.8313 0.0042	8 6.5783 0.3073	21
Total	30	27	26	83

Table of US_Exp by HR30				
US_Exp	**Comfort Level**			
Frequency Expected Cell Chi-Square	**1**	**2**	**3**	**Tota l**
1	8 7.2892 0.0693	2 2.3855 0.0623	1 1.3253 0.0798	11
2	26 25.843 0.0009	9 8.4578 0.0348	4 4.6988 0.1039	39
3	9 7.9518 0.1382	2 2.6024 0.1394	1 1.4458 0.1374	12
4	12 13.916 0.2637	5 4.5542 0.0436	4 2.5301 0.8539	21
Total	55	18	10	83

Table of US_Exp by HR40				
US_Exp	**Comfort Level**			
Frequency Expected Cell Chi- Square	**1**	**2**	**3**	**Total**
1	8 8.8795 0.0871	2 1.4578 0.2016	1 0.6627 0.1717	11
2	33 31.482 0.0732	4 5.1687 0.2642	2 2.3494 0.052	39
3	10 9.6867 0.0101	1 1.5904 0.2191	1 0.7229 0.1062	12
4	16 16.952 0.0534	4 2.7831 0.5321	1 1.2651 0.0555	21
Total	67	11	5	83

APPENDIX-C

Tables for Chi Square values for Motorways and Highways U.S Experience Vs Comfort Level

Table of State by MR00				
State	**MR00**			
Frequency **Expected** **Cell Chi-Square**	**1**	**2**	**3**	**Total**
MW	3 1.9753 0.5316	4 5.5309 0.4237	25 24.494 0.0105	32
NE	0 0.3086 0.3086	3 0.8642 5.2785	2 3.8272 0.8723	5
S	1 2.3457 0.772	6 6.5679 0.0491	31 29.086 0.1259	38
W	1 0.3704 1.0704	1 1.037 0.0013	4 4.5926 0.0765	6
Total	5	14	62	81
Frequency Missing = 2				

Table of State by MR10				
State	**MR10**			
Frequency **Expected** **Cell Chi-Square**	**1**	**2**	**3**	**Total**
MW	3 4.3457 0.4167	3 5.9259 1.4447	26 21.728 0.8398	32
NE	3 0.679 7.9336	1 0.9259 0.0059	1 3.3951 1.6896	5
S	4 5.1605 0.261	10 7.037 1.2476	24 25.802 0.1259	38
W	1 0.8148 0.0421	1 1.1111 0.0111	4 4.0741 0.0013	6
Total	11	15	55	81
Frequency Missing = 2				

Table of State by MR20				
State	**MR20**			
Frequency Expected Cell Chi-Square	**1**	**2**	**3**	**Total**
MW	7 9.8765 0.8378	11 8.6914 0.6132	14 13.432 0.024	32
NE	4 1.5432 3.9112	0 1.358 1.358	1 2.0988 0.5752	5
S	12 11.728 0.0063	10 10.321 0.01	16 15.951 0.0002	38
W	2 1.8519 0.0119	1 1.6296 0.2433	3 2.5185 0.092	6
Total	25	22	34	81
Frequency Missing = 2				

Table of State by MR30				
State	**MR30**			
Frequency Expected Cell Chi-Square	**1**	**2**	**3**	**Total**
MW	20 18.4 0.1391	6 7.2 0.2	6 6.4 0.025	32
NE	4 2.875 0.4402	0 1.125 1.125	1 1 0	5
S	19 21.275 0.2433	11 8.325 0.8595	7 7.4 0.021 6	37
W	3 3.45 0.0587	1 1.35 0.0907	2 1.2 0.533 3	6
Total	46	18	16	80
Frequency Missing = 3				

Table of State by MR40				
State	**MR40**			
Frequency **Expected** **Cell Chi-Square**	**1**	**2**	**3**	**Total**
MW	23 23.309 0.0041	6 6.321 0.0163	3 2.3704 0.1672	32
NE	4 3.642 0.0352	1 0.9877 0.0002	0 0.3704 0.3704	5
S	27 27.679 0.0167	8 7.5062 0.0325	3 2.8148 0.0122	38
W	5 4.3704 0.0907	1 1.1852 0.0289	0 0.4444 0.4444	6
Total	59	16	6	81
Frequency Missing = 2				

Table of US_Exp by HR00				
US_Exp	**HR00**			
Frequency **Expected** **Cell Chi-Square**	**1**	**2**	**3**	**Total**
1	1 1.4756 0.1533	2 1.3415 0.3233	8 8.1829 0.0041	11
2	4 5.0976 0.2363	3 4.6341 0.5763	31 28.268 0.264	38
3	3 1.6098 1.2007	1 1.4634 0.1467	8 8.9268 0.0962	12
4	3 2.8171 0.0119	4 2.561 0.8086	14 15.622 0.1684	21
Total	11	10	61	82
Frequency Missing = 1				

Table of US_Exp by HR10				
US_Exp	HR10			
Frequency Expected Cell Chi-Square	1	2	3	Total
1	1 1.7229 0.3033	3 2.7831 0.0169	7 6.494 0.0394	11
2	5 6.1084 0.2011	11 9.8675 0.13	23 23.024 252E-7	39
3	4 1.8795 2.3923	2 3.0361 0.3536	6 7.0843 0.166	12
4	3 3.2892 0.0254	5 5.3133 0.0185	13 12.398 0.0293	21
Total	13	21	49	83

Table of US_Exp by HR20				
US_Exp	HR20			
Frequency Expected Cell Chi-Square	1	2	3	Total
1	4 3.9759 0.0001	3 3.5783 0.0935	4 3.4458 0.0891	11
2	14 14.096 0.0007	12 12.687 0.0372	13 12.217 0.0502	39
3	6 4.3373 0.6373	5 3.9036 0.3079	1 3.759 2.0251	12
4	6 7.5904 0.3332	7 6.8313 0.0042	8 6.5783 0.3073	21
Total	30	27	26	83

Table of US_Exp by HR30				
US_Exp	**HR30**			
Frequency Expected Cell Chi-Square	**1**	**2**	**3**	**Total**
1	8 7.2892 0.0693	2 2.3855 0.0623	1 1.3253 0.0798	11
2	26 25.843 0.0009	9 8.4578 0.0348	4 4.6988 0.1039	39
3	9 7.9518 0.1382	2 2.6024 0.1394	1 1.4458 0.1374	12
4	12 13.916 0.2637	5 4.5542 0.0436	4 2.5301 0.8539	21
Total	55	18	10	83

Table of US_Exp by HR40				
US_Exp	**HR40**			
Frequency Expected Cell Chi-Square	**1**	**2**	**3**	**Total**
1	8 8.8795 0.0871	2 1.4578 0.2016	1 0.6627 0.1717	11
2	33 31.482 0.0732	4 5.1687 0.2642	2 2.3494 0.052	39
3	10 9.6867 0.0101	1 1.5904 0.2191	1 0.7229 0.1062	12
4	16 16.952 0.0534	4 2.7831 0.5321	1 1.2651 0.0555	21
Total	67	11	5	83